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Abstract
This paper provides a review of the literature on competitiveness and leakage concerns associated with differentiated climate abatement commitments among countries. The literature reviewed is not exhausted, but it is sufficient to provide a balanced view of both academics and policy circles. Section 2 discusses how to indentify the sectors at a risk of carbon leakage. Section 3 examines *ex ante* estimates of potential carbon leakage rates, and explains why they differ from *ex post* results of environmental tax reforms and greenhouse gas emissions trading schemes that have been implemented in the European Union. Section 4 discusses broad policy options to address competitiveness and leakage concerns, and compares which anti-leakage policy, border adjustments or output-based allocation, is more effective to limiting carbon leakages or mitigating production loss in the sectors affected. Given that border carbon adjustment measures are incorporated in the U.S. proposed congressional climate bills to level the carbon playing field and could have potential conflicts with World Trade Organization (WTO) provisions and practical difficulties associated with their implementation, Section 5 discuses in great detail the WTO consistency, the effectiveness and methodological challenges of border carbon adjustment measures. The paper ends with some concluding remarks.

JEL classification: F18; F47; O13; O24; O31; O44; Q37; Q42; Q43; Q48; Q54; Q55; Q56; Q58; R13; R15

Keywords: Emission trading; Competitiveness; Carbon leakage; Emissions allowance requirements; Carbon tariffs; Border carbon adjustments; Grandfathering; Output-based allocation; World Trade Organization

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1. Introduction

There is a growing consensus that climate change has the potential to seriously damage our natural environment and affect the global economy, thus representing the world's most pressing long-term threat to future prosperity and security. With greenhouse gas emissions embodied in virtually all products produced and traded in every conceivable economic sector, effectively addressing climate change will require a fundamental transformation of our economy and the ways that energy is produced and used. This will certainly have a bearing on world trade as it will affect the cost of production of traded products and therefore their competitive positions in the world market. This climate-trade nexus has become the focus of an academic debate (e.g., Bhagwati and Mavroidis, 2007; Brack et al., 1999; Charnovitz, 2003; Ismer and Neuhoff, 2007; Swedish National Board of Trade, 2004; The World Bank, 2007; Zhang, 1998b and 2004; Zhang and Assunção, 2004; Zhang and Baranzini, 2004), and gains increasing attention as governments are taking great efforts to implement the Kyoto Protocol and forge a post-2012 climate change regime to succeed it.

The Intergovernmental Panel on Climate Change (IPCC, 2007) calls for developed countries to cut their greenhouse gas emissions by 25-40% by 2020 and by 80% by 2050 relative to their 1990 levels, in order to avoid dangerous climate change impacts. In the meantime, under the United Nations Framework Convention on Climate Change (UNFCCC) principle of "common but differentiated responsibilities," developing countries are allowed to move at different speeds relative to their developed counterparts. This difference in climate abatement commitments could lead production of carbon-intensive products to move away from carbon-constrained countries to non- or less carbon constrained countries. This could in turn lead to losses of employment and economic output, in carbon-intensive sectors of these more carbon regulated countries. The fears of competitiveness losses undermine the support for abatement policy in developed countries. This could be particularly problematic for developed countries of distinct "regional" character, like Australia, Canada, and the U.S., partly because their provincial (or state) governments under the federal system are vested with significant political authority, and partly because energy-intensive industries are not spread evenly throughout these countries. Therefore, deterioration in the international competitiveness of energy-intensive sectors, while potentially economically disruptive in any country, could impose regionally uneven impacts on these countries (Rose and Zhang, 2004; Rose et al., 2006; Garnaut, 2008; Rivers, 2010).

Since greenhouse gases are the uniformly mixed pollutants, namely, one ton of greenhouse gas emitted anywhere on earth has the same effect as one ton emitted elsewhere, simply shifting production of carbon-intensive products from the carbon-constrained countries to non- or less constrained ones can reduce the environmental effectiveness of the regulating country's efforts. This phenomenon is referred to as carbon leakage.

Carbon leakage could be considered to be a kind of international externality (Markusen, 1975; Hoel, 1996). It is defined as the ratio of an increase in CO_2 emissions outside the countries taking domestic climate policies to a reduction in emission within these abating countries relative to their reference levels (Felder and Rutherford, 1993; IPCC, 2001 and 2007). Carbon leakage is mainly driven through two channels (IPCC, 2007; Reinaud, 2008b; Dröge et al., 2009; OECD, 2010).[1] One is the competitiveness channel. Countries that commit to emissions control will bear higher carbon costs than the competing counties without similar commitments. This will make their products most costly than products from the latter countries. So in the short term, this will cut their exports and lead to more products imported from countries without similar commitments. As a study for Noway suggests, this could be particularly a problem for a small country (Bruvoll and Fæhn, 2006). Over the longer term, this will lead to investment and production shift to the latter countries. This competitiveness-driven shifts of demand and production lead to shifts in emissions from carbon-constrained countries to countries without similar carbon constraints.

Another channel of carbon leakage is via the international fossil fuel channel. Carbon-constrained countries adopt stringent climate policies to cut their consumption of fossil fuels. This will push down the international prices of fossil fuels. These reduced prices will in turn induce an increase in fossil fuels in countries with less stringent climate policies, thus leading them to emit more. In virtually all applied economic models incorporating both channels, the larger part of carbon leakage occurs through this fossil fuel channel, rather than via the competitiveness channel (Babiker, 2005; Gerlagh and Kuik, 2007; Böhringer et al., 2010; Burniaux et al., 2008; Fisher and Fox, 2009). Fisher and Fox (2009) shows that for most energy-intensive sectors the leakage attributable to shifts in production is estimated to be 18-38% of the total carbon leakage when the U.S. unilaterally implemented a carbon tax of US$50 per ton of carbon emissions in several carbon-intensive sectors, implying that the remaining 62-88% is via the international fossil fuel channel. This suggests that any anti-leakage policies can be effective in reducing global emissions only if they can mitigate leakage from the fossil fuel channel. If most of carbon leakage is via this channel, border adjustments or output-based allocation, which unlike the carbon price do little to change relative fuel prices, can only reduce carbon leakage to a certain extent. Böhringer et al. (2010) shows that, in the case of the EU unilateral policy to cut its carbon emissions by 20%, these anti-leakage policies

[1] There are another two possible channels, both of which have not been addressed much empirically. One is the international cleaner goods price channel. Carbon-constrained countries typically increase the demand and thus international prices of goods used to reduce emissions. Consider the situation where the EU imports ethanol from Brazil to reduce its carbon emissions. This would lead Brazilian cars to rely more on gasoline, thus leading them to emit more (Quirion, 2010). Another channel concerns the leakage via interactions between policy instruments at different levels in the political system. For instance, in Europe the presence of EU ETS means that one Member State that introduces an additional policy instrument would lead to carbon leakage of 100% at the margin because total emissions are given by the sum of the national caps. Goulder and Stavins (2011) develops on this in more generic terms based on the co-existence of federal and state climate efforts in the US. They found that when the federal policy sets limits on aggregate emissions quantities, or allows manufacturers or facilities to average performance across states, the emission reductions accomplished by a subset of US states may reduce pressure on the constraints posed by the federal policy, thereby freeing facilities or manufacturers to increase emissions in other states. This leads to serious emissions leakage and a loss of cost-effectiveness at the national level.

cannot reduce the leakage by more than 33%, when compared with the full auction scenario. This is mainly because most of the leakage is due to lower global fossil fuel prices and increased demands for fossil fuels in other regions.

The fears of competitiveness losses and of carbon leakage are the main arguments against stringent climate policies, and in favor of sectoral exemption from a carbon pricing or free allocation of allowances. Competitiveness and leakage concerns are also the motivations of border carbon adjustments proposals (e.g., Zhang and Baranzini, 2004; Stiglitz, 2006; Subcommittee on Energy and Air Quality of the U.S. House of Representatives, 2008). In his opinion pages at *The New York Times*, economics laureate Paul Krugman points out that carbon tariffs are "a matter of leveling the playing field, not protectionism." (Krugman, 2009a)…they make sense, done right. I agree on both the economics and the legal aspects." (Krugman, 2009b).

This paper aims to provide a review of the literature on competitiveness and leakage concerns associated with differentiated climate abatement commitments among countries. The literature reviewed is not exhausted, but it is sufficient to provide a balanced view of both academics and policy circles. Section 2 discusses how to indentify the sectors at a risk of carbon leakage. Section 3 examines *ex ante* estimates of potential carbon leakage rates, and explains why they differ from *ex post* results of environmental tax reforms and greenhouse gas emissions trading schemes that have been implemented in the European Union (EU). Section 4 discusses broad policy options to address competitiveness and leakage concerns, and compares which anti-leakage policy, border adjustments or output-based allocation, is more effective to limiting carbon leakages or mitigating production loss in the sectors affected. Given that border carbon adjustment measures are incorporated in the U.S. proposed congressional climate bills to level the carbon playing field and could have potential conflicts with World Trade Organization (WTO) provisions and practical difficulties associated with their implementation, Section 5 discuses in great detail the WTO consistency, the effectiveness and methodological challenges of border carbon adjustment measures. The paper ends with some concluding remarks.

2. The identification of sectors at a significant risk of carbon leakage

A number of studies have quantified and compared the effects of carbon pricing on different industrial sectors to identify the sectors that are at a risk of carbon leakage. In so doing, two set of indicators are commonly used. One reflects carbon cost increase. Carbon cost includes both direct and indirect costs. The latter stem from a carbon cost mark-up for the production of electricity used by the sector. So the carbon cost indicator, or a value at stake, is defined as a ratio of the sum of direct and indirect carbon costs to the gross value added or turnover of a given industrial sector. Another indicator reflects trade intensity. It is the sum of imports and exports divided by domestic market or turnover plus imports. Hourcade et al. (2007) shows that for the United Kingdom 23 sectors are expected to exceed either 2% indirect carbon cost increase or 4% combined direct and indirect carbon cost increase relative to the gross value added under a carbon price of €20/t CO_2 and induced electricity price increases of €10/MWh, with cement, and iron and steel facing a cost increase of above 25%. But all the sectors with a value at stake of more than 2% (indirect carbon cost) or 4% (direct and indirect carbon costs) only account for 1.1% of UK GDP. With Germany having a higher than the EU average share of heavy industry, the value at stake reaches 2% of German GDP for the same carbon price (Graichen et al., 2008). For the EU as a whole, energy-intensive, including power generation, cement, refining, iron and steel, paper and pulp, petrochemicals, glass, and aluminium plus refining, accounted for less than 5% of the EU GDP and an even smaller share of jobs in 2005 (Ellerman et al., 2010). Much the same is true in the U.S. At a price of US$15 per ton of CO_2, output would fall by 2% or less in 80% of cases (Aldy and Pizer, 2009). A few industries - metals, paper, chemicals, cement and the like are both global and profligate enough to be at risk, but accounted for just over 3% of the U.S. GDP in 2005 and less than 2% of its jobs (Houser et al., 2008). Even the most vulnerable industries would shrink by 5% (Aldy and Pizer, 2009), and would not suffer the Armageddon that lobbying groups are predicting (*The Economist*, 2008b). These results are very much in line with the finding from an early study by the Annex I Expert Group on the UNFCCC (Baron and ECON-Energy, 1997). That study undertook a static analysis of the cost increases from a price of US$100 per ton of carbon on four energy-intensive industries (iron and steel, non-ferrous metals, paper and pulp, and chemical products) in the OECD countries. These sectors represent 3 to 7% of GDP and 1 to 4% of labour force. While the average cost increase measured as percentage of total production value differs among countries and sectors, it is generally low (below 2%) except for Australia and Canada. All these analyses suggest that other factors affecting price levels may well dwarf the price effects of a carbon price, at least at the rates that are generally considered in these studies.

The revised EU ETS Directive 2009/29/EC, adopted as part of the climate and energy legislative package in April 2009, details how to indentify the sectors at a risk of carbon leakage (European Commission, 2009a). Such sectors will also be identified based on their cost impact and trade-exposure, but the Directive relates to the thresholds different from those aforementioned empirical studies. According to the Directive, a sector would be deemed to be exposed to a significant risk of carbon leakage if one of the following three conditions is met:

- 5% cost impact and 10% trade intensity: (direct and indirect carbon costs) / gross value added ≥ 5% and (exports and imports) / (EU turnover and imports) ≥ 10%
- 30% cost impact: (direct and indirect carbon costs) / gross value added ≥ 30% or
- 30% trade intensity: (exports and imports) / (EU turnover and imports) ≥ 30%

In calculating the direct cost of the required allowances and the indirect cost from higher electricity prices resulting from the implementation of the Directive, the European Commission has assumed an allowance price of €30/t CO_2, 75% auctioning, and the average emission factor for electricity generation in the EU of 0.465 t CO_2 per MWh (European Commission, 2009b). As a general rule, the trade data for 2004-2006 and the CO_2 costs for 2005-2006 have been taken in these determinations. The quantitative analysis is carried out at the four-digit classification level of the NACE (Classification of Industries Established in the European Communities) (258 sectors in total), unless unavailable. The sectors identified to be at a significant risk of carbon leakage then qualify for receiving 100% of allowances for free along benchmarks for each of the sectors identified. No free allocation shall be given to electricity generators, meaning that even those sectors receiving all allowances for free will have to bear indirect cost from electricity price increase as a consequence of CO_2 price pass through in the electricity sector. For other sectors, the Directive suggests that 80% of allowances are handed out for free in the initial year of the third phase, with the share of free allowances declining to 30% by 2020, the end year of the phase. Such free allocations are based on the *ex ante* benchmarks that are set at the average performance level of the 10% most efficient installations in a given sector or subsector in the EU in the years 2007-2008 (European Commission, 2009a). This suggests that such benchmarks represent a challenge for some installations because they are set at the level of the best performers, but they are achievable by definition because they are derived from real practice in recent years.

These criteria sharply contrast with the original Commission proposal. The European Commission originally proposes only the first criterion. Following an intensive lobby from industry, the second and third criteria are included in the revised Directive. Moreover, most of the identified sectors are attributed to the third criterion. Of 146 sectors identified to be exposed to a significant risk of carbon leakage at the NACE 4-digit level, 117 sectors are due to the third criterion, showing a high trade intensity. Other 27 sectors have both significant CO_2 cost and trade intensity. Two sectors qualify due to the significant CO_2 cost criterion alone: cement (45.5%) and lime (65.2%) (European Commission, 2009b).

In H.R. 2998 (U.S. Horse of Representative, 2009), sectors eligible for allowance rebates are determined at the six-digit classification level in Codes 31-33 of the North American Industrial Classification System. A sector is determined to be eligible for allowance rebates if it meets with either of the following conditions.

- 5% energy or greenhouse gas intensity and 15% trade intensity: (energy or greenhouse gas costs) / the shipments ≥ 5% and (imports and exports) / (the value of its shipments and imports) ≥ 15% or
- 20% energy or greenhouse gas intensity: (energy or greenhouse gas costs) / (the value of its shipments) ≥ 20%

This bill specifies the annual average data for 2004-2006 to be used in these determinations, unless unavailable. However, the bill provides that U.S. Environmental Protection Agency shall determine additional sectors to be eligible if they 1) meet the energy or greenhouse gas intensity criteria at the time the rule is promulgated and 2) meet trade intensity criteria based on post-2006 data.

During deliberations of the bill, the Energy-Intensive Manufacturers' Working Group on Greenhouse Gas Regulation compiled a list of the sectors that meet with the eligibility criteria. 47 sectors are indentified to be eligible for allowance rebates (McMackin, 2009). This list is identical to the list compiled by the U.S. EPA (2009), with paperboard and beet sugar not included in the EPA list due to differences in data sources. This number is considerably less than the 148 sectors potentially covered by the EU Directive. The main reason for this difference is that not all EU criteria have taken into consideration the primary factors influencing a company's ability to compete under a carbon constraint: 1) the greenhouse gas intensity of its products, 2) its ability to pass on any increased costs to consumers without losing market share or profitability; and 3) its ability to mitigate carbon emissions (Parker and Grimmett, 2009). The 30% trade intensity criterion in the EU Directive alone has added 117 sectors to the list. They include everything from the manufacturing of wines to textiles. These sectors are trade-exposed, but are not considered to be carbon intensive. Based on a firm-level analysis of the EU ETS, Martin et al. (2012) finds that carbon-based criterion is a good indicator to measure the risk of downsizing whereas trade intensity criterion is not. Because trade intensity criterion is not related to carbon and thus allowance prices, these sectors identified based on the criterion will receive all allowances for free, even if the allowance prices are at the very low levels as they are now. Clearly, the European Commission has been extraordinarily generous in its identification of carbon leakage exposed sectors.

In screening sectors, both the EU and the U.S. have used a single approach across all sectors for free allowance allocations. Climate Strategies (Dröge et al., 2009) suggests that screening needs to take into consideration the cost structures and the investment options. That means that not only both direct and indirect costs, but also capital intensity of production, new investment need and the diversification of products should be considered. Moreover, screening should be linked with the best measures to address carbon leakage for that sector. Along this line, for sectors with high direct costs, if their production is capital intensive, reducing their carbon emissions needs new investment. Just like blast furnaces for steel production, the substitution of this process to cut carbon emissions needs new investment. A direct support could help steel firms not relocate elsewhere. If free allowances are applied, a new entrants reserve, which is set up to 5% of EU wide allowances during the third phase of the EU ETS from 2013 to 2020, could be used as an incentive for investors. On the other hand, if production is not capital intensive, and running a plant below full capacity is possible like clinker production, adjustments at the border work better for a homogenous product like clinker than for heterogeneous products (see Figure 1).

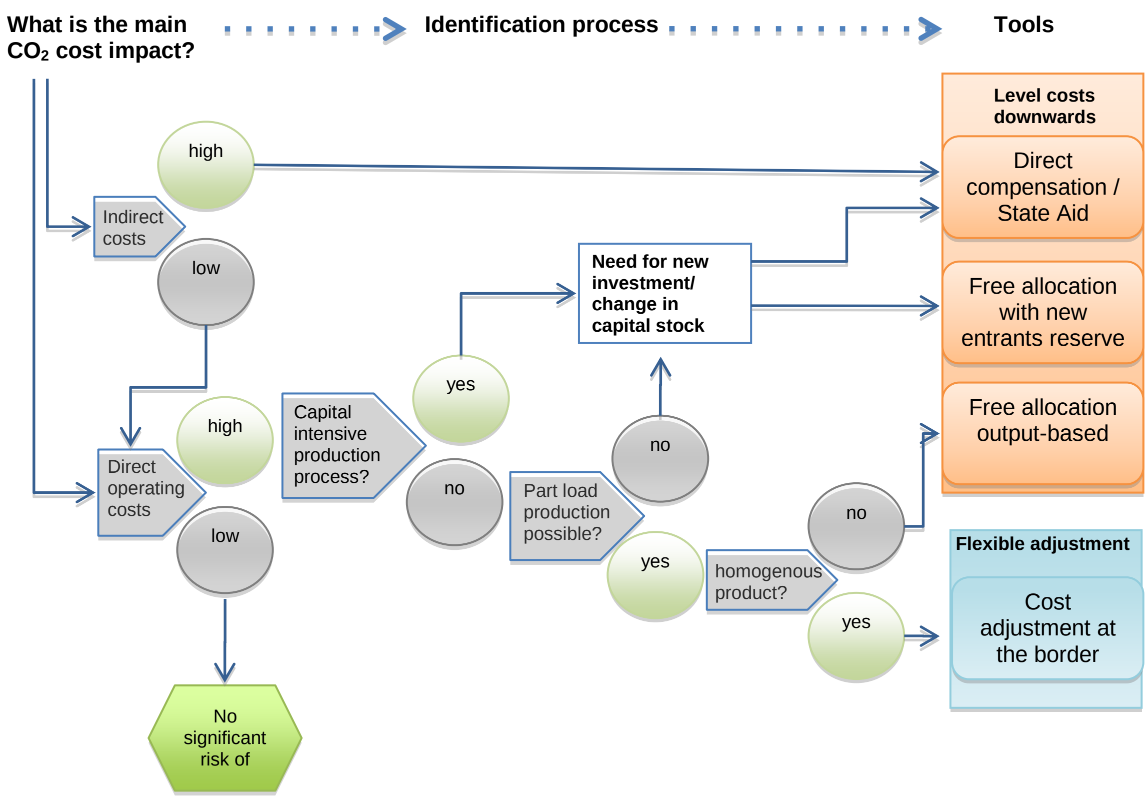

Figure 1 Screening of leakage potential
Source: Dröge et al. (2009).

3. How large is the magnitude of leakage impacts?

We will first discuss *ex ante* estimates of potential carbon leakage rates. We then examine the environmental tax reforms and greenhouse gas emissions trading schemes that have been implemented to provide an *ex post* assessment of their competiveness and carbon leakage impacts to see a difference, if any, with those *ex ante* studies. Finally, we will explain why they differ from each other.

3.1 *ex ante* studies at the aggregated and sectoral levels

There have been a large body of *ex ante* studies that have attempted to quantify leakage impacts of unilateral or uneven climate policies. Work in this area can be traced back to Pezzey (1992), Rutherford (1992), and Felder and Rutherford (1993). These and subsequent studies provide wide-ranging estimates of carbon leakages, depending on their assumptions on returns of scale, behaviors in the energy-intensive industries, price elasticity of demand, elasticities of trade substitution between domestic and imported products, supply elasticities of fossil fuels, transport costs, carbon cost pass-through capacity, and other factors (Burniaux and Martins, 2000; Mathiesen and Maestad, 2004; Babiker, 2005; Babiker and Rutherford, 2005; Gerlagh and Kuik, 2007; IPCC, 2007; Reinaud, 2008b; Carbone et al., 2009; Monjon and Quirion, 2011). For example, Burniaux and Martins (2000) shows that carbon leakages are highly sensitive to the assumed values of fossil fuel supply elasticities. Saito (2004) shows that the existing uncertainties in Armington (1969) elasticities whose values reflect how ease substitution between domestic and imported goods is, might not only affect the magnitude of policy effects, but possibly even the sign (positive or negative). When Armington elasticities are higher, foreign and domestic varieties of traded goods are close substitutes. This might result in stronger trade and leakage effects of climate policy. The carbon leakages via the international fossil fuel channel decrease with the supply elasticity of fossil fuels (Gerlagh and Kuik, 2007), and the carbon leakages linked to the competitiveness channel increase with the substitutability between domestic and imported products (Bernard and Vielle, 2009; Carbone et al., 2009). Moreover, a carbon leakage depends on the size of carbon-abating coalition. The more countries take carbon abatement, the less is the carbon leakage (Reinaud, 2008b; Böhringer et al., 2011; Carbone et al., 2009).

A literature review by IPCC (2007) suggests that the estimates of carbon leakages from implementing the Kyoto Protocol are generally in the range of 5-20% by 2010, very much in line with the range of 2-21% from the survey of Gerlagh and Kuik (2007) and 2-23% from the survey of Dröge et al. (2009). That is, for every five to twenty tons of cuts in CO_2 emissions in an abating country, one additional ton will be emitted outside this abating country.

One estimate slightly below the lower bound is from Mattoo et al. (2009). This World Bank study finds that the carbon leakage rate is only 1% when high income countries unilaterally cut their emissions in 2020 by 17% relative to their emissions levels in 2005. One reason for this rather small leakage effect is that while the unilateral emissions reductions by high income countries increase exports of carbon-intensive products from countries like Brazil, China and India, what matters for emissions is the impact on these countries' overall output and its composition. Since exports are a small proportion of output, the increase in output of carbon-intensive sectors in these three countries is only about 1-2%. Another reason is that this expansion of these energy-intensive sectors pulls resources out of other sectors, which has an offsetting effect on emissions.

One notable outlier significantly goes beyond the upper bound in the three surveys, reporting a leakage rate of 130% (Babiker, 2005). Leakage rates above 100% mean that carbon reduction in one region is more than offset by emission increase outside this region, thus leading to more global emissions rather than less. This is not impossible if implementing a strict climate policy imposes additional costs on energy- and carbon-intensive industries being unable to pass on these costs to their consumers. This will drive demand and production of products and the resulting emissions to the shifts from carbon-constrained countries to countries without similar carbon constraints. Given that emissions intensities in the abating countries are typically lower than in the non-abating countries, such a shift would lead to more emissions for producing per unit of like product. However, this outlier rests on two assumptions: the homogeneity of goods and increasing returns to scale, which differ from the usual assumptions of products differentiation and constant returns to scale under the computable general equilibrium modeling. Babiker (2005) shows that when perfect homogeneity is assumed, increasing returns to scale assumption increase a carbon leakage to 130% from 60% under the constant returns to scale assumption. By contrast, in the case of the differentiated trade in products, increasing returns to scale assumption only produces a carbon leakage rate of about 25%. Clearly, this homogeneity assumption alone, no matter of returns of scale, has a significant effect on a carbon leakage. Carbone et al. (2009) supports this finding, suggesting that carbon leakage becomes a considerable problem when traded goods from different regions are close substitutes under the assumption of homogeneity of goods (homogenous trade).

The aforementioned carbon leakages are estimated at the aggregated level. But because energy-intensive industries are major carbon emitters, it should come as no surprise that climate policies have targeted at these industries, such as steel, cement and aluminum. These sectors are relatively open to international trade, ease to relocate and have some degree of product and process uniformity—consumers tend to be indifferent to the origins of these products, provided that they are less expensive. Therefore, these energy intensive sectors are exposed to a great risk of carbon leakage. The aggregated numbers hide very different carbon leakages at the sector level. Thus, assessing carbon leakage needs to focus on more detailed sectors (Monjon and Quirion, 2011).

An increasing number of sectoral (bottom-up) studies have taken into consideration of the specific energy-intensive industries in order to investigate the effects on production and location decisions by firms, thus determining how large leakage rates are for these sectors exposed to global competition. Given that higher leakage rates would be expected for more trade-intensive sectors and that steel is much more traded on an international level, let us take the iron and steel sector as an example. Gielen and Moriguchi (2002) develops STeel Environmental strategy Assessment Program (STEAP), a large scale partial equilibrium model that covers the life cycle analysis of many different technology options in the iron and steel sector. They find that if Japan and Europe alone introduced such a carbon tax, their CO_2 emissions would indeed decline, but that lower production in these regions would be offset by increased production and emissions elsewhere. They show that a tax of US$10-42/t CO_2 would generate a carbon leakage rate of 35-75% by 2020 in the iron and steel sector. According to the STEAP model, marginal tax increases lead to much higher increases in leakage at low tax levels (US$10–50/t CO_2) than at high tax levels (around US100/t CO_2 and beyond). This non-linear behavior indicates a strong sensitivity of leakage to small tax increases compared to the status quo (Oikonomou et al., 2006). A study by the OECD (2003) also concludes that an OECD-wide carbon tax of US$ 25/t CO_2 in the steel sector would lead to a carbon leakage rate of 45% in the steel sector. If the implementation of this carbon tax at the same level is not coordinated across OECD countries, rather unilaterally, this leakage rate then would, on average, increase to 60%. Using a global partial equilibrium model of the steel industry, Mathiesen and Maestad (2004) simulates potential effects on world CO_2 emissions of the introduction of a US$ 25/t CO_2 tax in the steel sector in Annex I countries. That would lead to a carbon leakage rate of 26%. If the substitution possibilities between different types of steel and between inputs to steel production were not included, this estimated leakage rate in the steel industry would double, increasing to 53%. Quirion (2009) applies a small partial equilibrium model that uses marginal abatement costs from the large POLES (Prospective Outlook for the Long term Energy System) model. Their results suggest a leakage rate of 45% in the steel sector for a 15% reduction in emissions in the EU in 2015 relative to 2005 levels.

Clearly, the estimated carbon leakage rates in the iron and steel sector differ greatly with the models and assumptions used in these sectoral studies. However, none of these simulations at sectoral levels have indicated a leakage rate near 100%. This implies that it is highly unlikely that carbon leakage would offset entirely carbon abatement in a given industry. This is different from the aforementioned studies at the aggregated level, which indicate that carbon leakage rate could be above 100% under the specific assumptions.

3.2 *ex post* studies on ETRs and ETS

The OECD countries, in particular the EU member states, have implemented environmental tax reforms and greenhouse gas emissions trading schemes. These experiments provide a basis for an *ex post* assessment of their competitiveness and carbon leakage impacts to see a difference, if any, with those *ex ante* studies. A body of *ex post* studies, although there are a few, have examined their impacts after implementing these market-based environmental instruments and have compared with the references before the introduction of these instruments (Agnolucci, 2009; Andersen et al., 2007; Andersen and Ekins, 2009; Barker et al., 2009; Ellerman and Buchner, 2007 and 2008; Enevoldsen et al., 2007; Convery et al., 2008; Reinaud, 2008b; Ellerman et al., 2010; European Commission, 2012c; Grubb, 2012; Kettner et al., 2012).

Let us start with environmental tax reforms. Staring in Finland and Sweden in 1990, a number of European countries have implemented environmental tax reforms (ETR), shifting the burden of taxes from 'goods' (e.g., labor and capital) to 'bads' (e.g., carbon emissions). Since environmental taxes serve to correct market failures, such a tax shift could improve short-term economic performance, while delivering a long-term environmental dividend, thus leading to the so-called double dividend (Pearce, 1991). The COMETR (COMpetitiveness effects of Environmental Tax Reforms) project (Andersen et al., 2007; Andersen and Ekins, 2009) is a comprehensive attempt to provide an *ex-post* assessment of the environmental and economic effects of the ETRs implemented in seven EU member states (Denmark, Finland, Germany, the Netherlands, Slovenia, Sweden, and the UK) at the macro level as well as at a sector level. Generally speaking, the Nordic countries generally provide the firmest basis for an *ex-post* assessment because they have time series of more than a decade since the introduction of ETRs, in comparison with Germany and UK where carbon-energy taxes were introduced only in 1998 and 2000. In order to disentangle the specific impact of the ETRs, two scenarios were developed with the E3ME model, a comprehensive time-series estimated macro-economic model of eleven different fuels and more than 40 economic sectors within the EU. One scenario is labeled as the 'baseline case'. This scenario was calibrated closely to the observed outcomes over the historical period from 1994-2003 for all seven EU member states with ETRs and the rest of the EU, using historical data that include the effects of ETR implementation. Another scenario is termed as the 'counterfactual reference case'. This reference scenario basically involved a projection of 'what if' there had been no tax shifting as a result of the ETRs, keeping everything else in the model constant but including current and expected developments in the EU economy (Barker et al., 2009). This counterfactual exercise allows to isolate the effects of the ETRs.

Barker et al. (2009) suggests that the double dividend theory proves true. All six EU member states experience reduced CO_2 emissions but none of them experience negative GDP. No reduction is identified in Slovenia, which in fact mainly relabeled its pre-existing mineral oils tax into a CO_2-tax. By 2004, the ETRs had, on average, led to reductions in greenhouse gas emissions of 3.1% for the six member countries. The largest reduction in emissions occurs in Finland and Sweden, as a result of their highest tax rates. By contrast, the ETR is not particularly efficient in reducing emissions in Germany as coal was not included. Depending on how the revenues from environmental taxes are recycled, five of the ETR countries have an increase in GDP. In Sweden, the effects take slightly longer to come through, as the very large increase in household electricity taxes depresses real incomes in the short run. Finland experiences a short-term GDP boost from the effects of the taxes on fuel demand, because a reduction in the demand for imported fuel improves its trade balance. In the UK there is the no discernable effects on GDP. This can be attributed to the fact the scale of tax rates (i.e., climate change levy on fossil fuels) levied and the revenues generated and recycled back to the economy has been rather modest (Andersen et al., 2007; Barker et al., 2009).

Up to now, an assessment is made on the ETR countries. It would be interesting to see how the ETR countries perform relative to countries that have not implemented the ETR, i.e., non-ETR countries. Barker et al. (2009) and Ekins (2012) show that the ETR countries experience slightly faster GDP growth than they had without the ETR, and the non-ETR countries in the EU show practically no change. This suggests that, far from damaging the competitiveness of ETR countries compared to the non-ETR countries, the ETR countries benefit economically, as well as environmentally with CO2 emissions falling in the ETR countries collectively, from the ETR policy. Moreover, the ETRs have almost no effect on the level of CO2 emissions in the non-ETR countries (Figure 2). This suggests that there was no carbon leakage from the ETR countries collectively to the non-ETR countries in the EU.[2]

[2] However, an important caveat exists as the E3ME model from which the results are derived is not a world model, implying that the abovementioned result is limited to the EU member states.

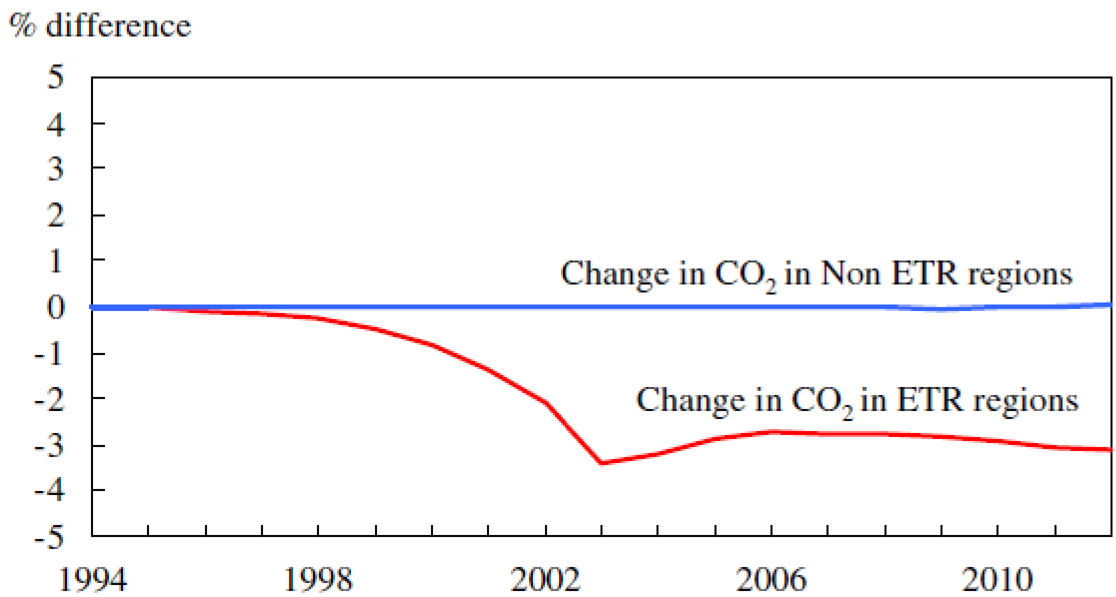

Figure 2 Changes in CO_2 emissions in the ETR and non-ETR countries (% difference between the base case and the counterfactual reference case)
Source: Speck (2007).

Ekins and Salmons (2007) and Miltner and Salmons (2009) have analyzed *ex-post* effects of the ETR on the following eight sectors at NACE 3-digit level in the seven EU member states: Meat and meat products (15.1), paper products (21.2), basic chemicals (24.1), pharmaceuticals (24.4), glass and glass products (26.1), cement, lime and plaster (26.5), basic ferrous metals (27.1-3), and basic Non-ferrous metals (27.4). They examine the changes in competitiveness indicators (the share of global production, import intensity and export intensity) for each country and each sector according to the percentage change in unit cost of production. Table 1 lists the results for the 56 combinations of eight sectors and seven countries.

Table 1 Sectoral competitiveness analysis in the ETR countries

% change in unit costs	Gain in competitiveness	No change in competitiveness	Loss in competitiveness	Total
Less than 1%	2	39	9	50
1%-5%	0	5	0	5
More than 5%	0	1	0	1
Total	2	45	9	56

Source: Ekins and Salmons (2007).

The ETRs have not been significant in terms of their impact on unit costs of production (below 1% in 50 cases). Moreover, losses in competitiveness occur only in countries/sectors where the impact of the ETRs on unit costs has been no larger than 1%. There is no case of a decrease (or increase) in competitiveness where the impact of the ETRs was above 1%. Out of 56 cases considered, the results do not support for a change in competitiveness in 45 cases (namely, 80% in 56 cases) relative to their competitors. Put another way, competitiveness in 45 cases does not change with or without the ETRs relative to their competitors. Only in nine cases (16%) do the trends in the indicators suggest a loss in competitiveness. These occur in the UK (sectors 15.1, 21.1, 27.1-3, 27.4), Germany (21.2, 24.4, 26.1), Finland (24.4) and the Netherlands (27.4). In 4% of 56 cases, there is actually an improvement in competitiveness in the Danish pharmaceuticals industry and the Dutch meat processing sector (Miltner and Salmons, 2009). However, some qualifications need to be added to this finding. A comparison of ETRs applied to the aforementioned eight sectors in Denmark, Finland, Germany and the UK reveals that, although with exceptions, sectors of low energy intensities tend to have high or medium tax rates, while sectors of high energy intensities have low or medium tax rates (Miltner and Salmons, 2009). In absolute terms, unilateral energy/carbon taxes in these countries have been modest, and for the most energy-intensive sectors, they are very low indeed or to some extent symbolic (Andersen et al., 2007; Andersen and Ekins, 2009; Miltner and Salmons, 2009).

Now let us turn into emission trading experiments. Since January 2005, the EU put into operation the world's largest multi-country, multi-sector carbon dioxide emissions trading scheme (ETS). The EU ETS has provided a large-scale experiment to identify the magnitude of competitiveness and carbon leakage. Analysis of cement, iron and steel, aluminum and refinery sectors does not reveal carbon leakage for these trade-exposed carbon-intensive sectors during the first phase (2005-2007) of the EU ETS. There is also no evidence that the EU ETS in place has triggered changes in trade flows and production patterns in these sectors during this phase (Reinaud, 2008b). These *ex post* results from this world's unprecedented, grand climate policy experiment are in sharp contrast with *ex ante* studies that have projected much higher carbon leakage effects.

3.3 Why *ex post* results differ from *ex ante* projections?

There are two sets of explanations for this difference. The first set of explanations are related to the assumptions and data used by *ex ante* studies that do not reflect the reality of the EU ETS. Another set of explanations for *ex ante* overestimate of the net leakage effects concern the shortcomings of models themselves that omit the potential positive impacts of climate policy.

Let us start with the first set of explanations for this difference. First and most importantly, this is due to the free allocation of allowances to the entities covered under the EU ETS. The EU ETS Directive allowed member states to auction up to 5% of allowance allocations in the first phase 2005-07, rising to 10% in the second phase 2008-12. In the first phase, only four of 25 member states used auctions at all, and only Denmark auctioned the full 5% (Ellerman and Buchner, 2007). As a result, auctioned allowances accounted for 0.13% of the total allocation (Convery et al., 2008). In the first four years of the second trading phase, auctioned volumes increased, but only accounted for about 4% of total allowances issued (European Commission, 2012c). Moreover, in most cases allowances are over-allocated to the industry sector, with electricity and heat generation being the only sector that exhibits a shortage of allowances in all trading years from 2005 to 2010 (Kettner et al., 2012). Put another way, not only receiving allowances for free, the industry sector even gets more than its needs. Analysis of the Community Independent Transaction Log data suggests the number of the allocated allowances 7% above the level of reported emissions for cement and lime installations in the first phase (Ellerman and Buchner, 2008). This surplus of allowances reaches about 17.5% for the iron and steel sector (Convery et al., 2008) and about 20% for the pulp and paper sector. For the EU 23 (the old EU 15 plus 8 new member states from Eastern Europe) as a whole, verified emissions are 3.1% less than their baseline emissions (Ellerman and Buchner, 2008) (see Box 1). The over-allocation of allowances has led to significant drop in allowance prices. When Belgian, Czech, Dutch, and French verified emissions were released, it was shown that their emissions were much lower than that allowed. This surplus of allowances let to allowance prices dropping by 55% in only three days. The price dropped from a record high of €31/t CO_2 in mid-April to only €13.5/t CO_2 by 27 April 2006 (Zhang, 2006). In the second trading phase the European Commission took more tough position in limiting the Member States' generous allocations in their initial National Allocation Plans. Most proposed national caps had to be adjusted downwards by the Member States after the European Commission's review process. This led to substantial changes in allocation discrepancies for several Member States, in particular the Baltic States (Capoor and Ambrosi, 2008). In the first trading phase the New Member States generally exhibited higher net long positions than the EU-15 and only one of the New Member States (Slovenia) but five EU-15 countries were in a net short position. In the first three years of the second trading phase, these regional differences largely disappeared as a result of the Commission's intervention in National Allocation Plans (Kettner et al., 2012). As a result, the overall EU cap for 2008 was binding, with verified emissions exceeding allocated allowances on aggregate by 5.3%. For 2009, because of the exogenous shock of the economic crisis to the installations in the trading system, however, allocation again exceeded verified emissions by 8.8%. For 2010 emissions moderately increased, but allocated allowances still exceeded verified emissions. This surplus gap become even bigger in 2011 because a decline in verified emissions as a result of continuous economic growth stagnation. Overall, verified emissions exceeding allocated allowances on aggregate by 5.2% during the period 2008-11 (European Commission, 2012c). Despite the European Commission's tough position in limiting the Member States' initial generous allocations for the second phase, this period will end up with a huge volume of unused emissions allowances that can be banked forward into the third phase. Estimates of this surplus differ. The Commission's own estimate suggests that this surplus potentially represents the equivalent of 2.4 billion tons of allowances by 2020 (European Commission, 2012a), while other estimate puts this surplus at 3.1 billion tons of allowances (Morris, 2012). For electricity-intensive sectors like aluminum, the still functioning long-term electricity contracts limit their actual exposure to rising electricity prices. Only 18% of the EU capacity operated without long-term electricity contracts. While the details of these contracts are unknown, cost estimates suggest lower average electricity costs in these cases than for smelters in Germany and the Netherlands acquiring electricity on the market. The two countries see that their power prices doubled during the period 1999-2006, relative to small changes in other EU member states (Reinaud, 2008a; Convery et al., 2008). Furthermore, booming demand for aluminum and other commodities has kept their prices high, thus making all manufacturers profitable. Given that any impacts of the carbon prices on industry are likely to be felt more strongly when markets are less favorable, high commodity prices during the period 2005-07 make it difficult to observe any effects of carbon prices on these sectors' profitability. Product specifications that vary from country to country, meanwhile, help to protect European refiners from foreign competition (*The Economist*, 2008; Reinaud, 2008b; Convery et al., 2008).

Box 1 Over-allocation or abatement in the pilot phase of the EU ETS?

A long position has been widely interpreted as evidence of over-allocation of allowances. However, it is unsettled whether it is a result of over-allocation, abatement, or both. A surplus of allowances could be because of an over-estimate of the level of CO_2 emissions and the consequent demand for allowances as a result of rising real output, the adverse weather in 2005 and the higher prices of natural gases relative to coal, which would have driven increased use of coal and thus lead to increased emissions and demand for the allowances. Another possibility for a surplus of allowances could be an under-estimate of the amount of abatement that would occur as the affected facilities incorporated carbon prices into their production decisions. Ellerman and Buchner (2008) argues that this under-estimate of the amount of abatement is a distinct possibility, given that a significant price was paid for CO_2 emissions during the period 2005-06, which would have the effect of abating CO_2 emissions as firms adjust to this new reality (Convery et al., 2008). Their preliminary estimate shows that the EU ETS had reduced at least 50 million tons of CO_2 emissions annually. Therefore they conclude that only a relatively small proportion of the observed long position of nearly 60 million tons for the EU as a whole in 2005-06 can be attributed to over-allocation. Anderson and di Maria (2011) also supports the contribution of abatement activities by analyzing abatement and over-allocation in the ETS pilot phase based on a dynamic panel data model. Using data on historical CO_2 emissions, economic activity, electricity prices and climate factors they find a net abatement of 173.5 million tons of CO_2 emissions in the pilot phase. Based on a review of published estimates, Grubb (2012) suggests an average yearly abatement since the establishment of the EU ETS in the range 30-70 million tons of CO_2 emissions, roughly 2-4% of the total emissions covered.

Now let us move to the second set of explanations for the difference between *ex ante* projections and *ex post* results. Copeland and Taylor (2005) has developed a theoretical model that examines a carbon unconstrained country's best response to a carbon emissions reduction in the emissions constrained country. Taking into account a free rider effect, carbon leakage (a substitution effect), and an income effect, they show that in an open trading world, unilateral emission reductions by a set of rich Northern countries can create self-interested emission reductions by the unconstrained poor Southern countries. The rational is that since the unconstrained country is a dirty good exporter, its emissions will tend to rise via free rider effects and substitution effects in production, but will tend to fall via substitution and income effects in the demand for environmental quality. Overall, the increase in emissions in the unconstrained country may be small or even zero.

High estimate of carbon leakage is because modeling studies have typically regarded the technology in each country as given. They do not take into account induced technological innovation and diffusion brought about by the implementation of climate policies. In the short to medium term with production capacities largely given, this does not seem like a major restriction. However, in the longer term, considerable technological developments could take place in the sector if carbon taxes or tradable permits were to be applied. Indeed, there is evidence that abatement technologies are endogenous, and thus technology development is affected by energy policies or environmental policies (Newell et al., 1999; Jaffe et al., 2002; Löschel, 2002; Popp, 2002). Grubb et al. (2002) has estimated the potential impact of international spillovers due to mitigation actions by the industrialized countries on greenhouse gas emissions in the developing countries. They show that spillovers from Annex I mitigation actions, via induced technological change, could have sustainable effects on sustainable development, with emission intensities of developing countries at a fraction of what they would be otherwise. Golombek and Hoel (2004) demonstrates that with endogenous technologies and technology diffusion between countries, reduced emissions in some constrained countries might also reduce emissions in other unconstrained developing countries. Bossetti et al. (2008) examines effects of international energy research and development (R&D) spillovers on the costs of stabilizing atmospheric CO_2 concentrations at 450 ppmv at the end of the 21st century by analyzing a policy-mix in which a climate policy based on a global permit market is coupled with a technology policy based on transfers. They show that global stabilization costs would be much lower when resources are used to increase the absorption capacity in developing countries, instead of a simpler, non-targeted, lump-sum transfer of the same amount of resources from high income countries to developing countries. This is because existing barriers have prevented developing countries from absorbing international knowledge spillovers.

In empirical energy and climate modeling studies on the spillover effects, induced technological change can be implemented via R&D and learning-by-doing (LBD) channels (Sijm et al., 2004; IPCC, 2007; Gillingham et al., 2008; Pizer and Popp, 2008). Through R&D channel, the introduction of climate policies increases the market for carbon-mitigation technologies and thus creates an incentive for increased R&D investments in these technologies. In modeling terms, these increased investments lead to an increase of the knowledge capital stock. Models used to endogenize the effect of R&D on technology and mitigation costs have generally included a variable representing R&D that influences economic behavior through one of three routes: a direct impact on the level of emissions intensity, a reduction in the mitigation cost function, or productivity gains in sectoral production functions (with sector-specific R&D stocks in multi-sectoral models) (Pizer and Popp, 2008). Depending on approaches to modeling spillovers and opportunity costs, studies differ regarding effects from endogenizing R&D, with relatively small effects found from Nordhaus (2002) and much larger effects from Buonanno et al. (2003).

LBD channel means that climate policies encourage primarily the adoption of carbon-mitigation technologies, resulting in declining costs of these technologies due to the accumulation of knowledge and experience as the installed capacity of these technologies expands. In modeling terms, this process of technological change is expressed by a learning curve that relates the costs of a technology to its cumulative installed capacity (Sijm et al., 2004). Söderholm and Sundqvist (2007), and Söderholm and Klaassen (2007) have extended this basic presentation to estimate "two-factor" learning curve that models cost reductions of a technology as a function of both its cumulative capacity (LBD) and R&D (learning by searching). Söderholm and Sundqvist (2007) find that learning by searching, rather than learning by doing, contributes more to cost reductions. The literature on learning curve shows that a number of new low-carbon technologies for power generation have indeed experienced significant cost reduction as they are progressively deployed (McDonald and Schrattenholzer, 2001; Junginger, 2005; IPCC, 2007; Junginger et al., 2010). Given that learning tends to be thought of as a technology-specific phenomenon, disaggregated, technology-oriented bottom-up models for energy and climate policy analysis have widely incorporated learning for each technology. Sijm et al. (2004) find that most top-down modeling studies omit the spillover effect or show it playing a minor role. They point out that while the potential beneficial effect of technology transfer to developing countries arising from technological development brought about by Annex I action may be substantial for energy-intensive industries, it has so far not been quantified in a reliable manner. Even in a world of pricing CO_2 emissions, there is always likelihood that net spillover effects are positive, given the unexploited no-regret potentials and the technology and know-how transfer by foreign trade and educational impulses from Annex I countries to Non-Annex I countries (Sijm et al., 2004). In any case, they conclude that, in practice, carbon leakage is unlikely to be substantial because transport costs, local market conditions, product variety and incomplete information all favor local production (Sijm et al., 2004; IPCC, 2007).

Regardless of these mechanisms and considerations, how baselines are simply defined in *ex ante* studies matter. The abating countries expect some anticipated technological changes induced by existing polices even in the baselines. This is particular true for R&D that improves energy efficiency, which is encouraged by higher energy prices that may or may not be the result of environmental policy (Popp, 2002).Thus, appropriate baselines for any model that is calibrated to current data trends should incorporate anticipated changes not directly as a result of climate policy, rather by the existing policies. If baselines simply assume no policy, that would set high baseline for the abating countries relative to baselines for non-abating countries than if baselines incorporate the existing policies. That will lead to higher *ex ante* carbon leakage rates.

There is some evidence for a first-mover advantage for specific renewable energy technologies, e.g., wind power and solar photovoltaics (PV) for Germany. The development of solar PV in Germany shows that having an appropriated policy does make a difference. While Germany has unfavorable solar radiation conditions compared with its Southern European countries, thanks to feed-in tariffs, it leads the world in both accumulated installations and new photovoltaic additions. Its cumulative PV installations through 2009 were more than the sum of the next 9 ranked countries combined (Kazmerski, 2011). Summerton et al. (2012) provides a model-based macroeconomic assessment of first-mover advantage (FMA) in environmental technologies, in which a

European sector becomes world leader and captures the global market for a particular technology. Defining FMA as the opportunity to capture market share by being the first to develop a new technology and establish incumbency, and using the E3MG model, Summerton et al. (2012) considers four scenarios where the EU is able to capture FMA in all renewables, wind and solar technologies, and motor vehicles, with the EU's FMA gradually eroding over time, and becoming zero after ten years. It is found that some of the sectors that benefit the most are also those that could be expected to lose out from higher energy prices. The model results also show that FMA could provide a small but noticeable boost to European GDP and employment, which could go some way to countering losses in production from implementing ambitious climate policy.

This is consistent with the Porter hypothesis (Porter, 1991; Porter and van der Linde, 1995),[3] which suggests that well-designed environmental regulation can spur innovation and improve competiveness by spurring innovation. Such innovation would provide a first mover in low-carbon technologies a competitive edge over their competitors. In the aforementioned *ex-post* studies on the effects of the ETRs applied to the eight sectors in the four EU member states, defining that consistency with the Porter hypothesis would be if the change in the energy costs as a result of the introduction of the ETRs is lower than the savings in energy costs in a given period, Miltner and Salmons (2009) shows that there is some evidence of consistency with the Porter hypothesis. Only the glass sector (26.1) shows consistency with the Porter hypothesis in all four member states, and the basic chemicals sector (24.1) in all but one. In all other sectors, two EU member states show consistency and two do not. Overall, out of 32 cases considered, 19 cases would be consistent with the Porter hypothesis, and 13 cases not. But no studies have modeled this conveyed by the early implementation of clean energy or climate policy. This also leads to the overestimate of the net carbon leakage.

4. Options to address competitiveness and leakage concerns

Ex post analyses of the EU ETS helps us better understand competitiveness and carbon leakage impacts of the EU ETS. However, the insights from such analyses are of limited value for the future. Its relatively short time span does not allow to observe the full potential effects on the covered installations. The EU has planned more ambitious emissions reduction targets and more use of auctioning post-2012 (European Commission, 2009a). Therefore the EU ETS will become a much stricter scheme with a rising share of auctioning on the one hand and a decreasing yearly amount of the overall allowances to be handed out to industries on the other hand in the third phase 2013-2020 and beyond. Despite the European Commission's tough position in limiting the Member States' initial generous allocations for the second phase, because of the economic recession and because a number of regulatory changes regarding the cap setting and allocation of allowances kick in as of 2013, this period will end up with a huge volume of unused emissions allowances of 2.4 billion tons or more, which can be banked forward into the third phase (European Commission, 2012a). The European Commission has recognized

[3] See Ambec et al. (2011) for an overview of the key theoretical and empirical insights into the Porter hypothesis to date.

the impact of the growing surplus of allowances, proposing back-loading auction volumes up to 1.2 billion tones of allowances from 2013-15 towards the end of the third phase (European Commission, 2012b,c). In addition to this simplest mechanism to set aside allowances, other proposed options to strengthen the EU ETS include tightening the greenhouse gas reduction target and the ETS cap and trajectory and undertaking reserve price auctions (Grubb, 2012). By establishing a *de facto* floor price for the EU ETS, the latter will remove downside risks for investors. Undertaken properly and timely, these measures would help restore a higher carbon price. As would be expected, the costs of abating carbon are expected to rise in the carbon constrained EU or other countries that take comparable climate actions, relative to the rest of the non- or less carbon constrained world. While implementing strengthened ETS and other climate policies and measures is aimed to cut carbon emissions, these countries have to look for options to level the carbon costs in order to avoid putting industries exposed to a risk of carbon leakage at a competitive disadvantage vis-à-vis their trading partners.

A number of policy options have been widely discussed, and in some cases deployed to address competiveness and leakage concerns. This section discusses broad policy options to avoid putting industries exposed to a risk of carbon leakage at a competitive disadvantage,[4] while the next section focuses on border carbon adjustment measures that are incorporated in the U.S. proposed congressional climate bills to level the carbon playing field and raise great controversies.

4.1 Global approach

Clearly, the global approach is the best approach to leveling the carbon costs. The ideal solution is to have a legally binding international agreement that covers all countries, at least all major emitting economies, and sets their emissions limits. Such an agreement will enable to internalize the carbon costs and establish a global carbon price framework, thus leveling the carbon playing field. Although there is some positive sign in international climate change negotiations, such an agreement will not come any time soon. This decision (FCCC/CP/2011/L.10) on the Establishment of an *Ad Hoc* Working

[4] While it is not discussed in this paper, it should be pointed out that crediting mechanism like the clean development mechanism under the Kyoto Protocol has the potential to reduce carbon leakage and mitigate competitiveness, because it lowers the carbon price differential with non-regulating countries, which is an important driver of leakage (Kallbekken, 2007; Burniaux et al., 2009). However, whether crediting mechanism reduces carbon leakage depends partly on appropriate setting of the baseline against which credits are granted (Kallbekken et al., 2007). Moreover, high transaction costs of and barriers to implementation of the CDM, such as lack of capacity to identify and assess potential projects in host countries, risk and uncertainties associated with generating certified credits, and delays in approving CDM projects, limit its potential to lower carbon leakage, because not all potential CDM projects will be implemented. The size and nature of fossil fuel markets matter too. Trade is more regional or local for coal than for oil. CDM projects reduce fossil fuel prices in local markets. This results in increased fossil fuel use and increased carbon emissions. The CDM may then increase carbon leakage (Bollen et al., 1999; Rosendahl and Strand, 2011).

Group on the Durban Platform for Enhanced Action, is part of the Durban Package, and launches a process to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all parties, through a new subsidiary body under the Convention known as the *Ad Hoc* Working Group on the Durban Platform for Enhanced Action, starting its work in the first half of 2012 (UNFCCC, 2011). The more realistic alternative is to establish global sectoral agreements.[5] Such cooperative sectoral agreements aim at engaging specific sectors in non carbon-constrained countries and eliminating, at least reducing carbon-cost differences among countries of uneven climate policies, thus restoring a level carbon playing field. To what extent global sectoral agreements can address competitiveness and leakage concerns depends on specific forms that such agreements take. One form is to establish global sectoral agreements among companies within a given sector. Some industry-led agreements, e.g., the Cement Sustainable Initiative (CSI) led by the World Business Council for Sustainable Development, take this approach. The CSI gathers 22 major cement producers with operations in more than 100 countries, which collectively account for about one third of the world's cement production. This initiative involves capping emissions for companies operating in countries with mandatory mitigation obligations, and setting intensity-based targets for developing countries which would be differentiated to reflect national production constraints in the cement sector.[6]

Sectoral agreements could also take the form of sector-specific performance standards. However, past experience shows that the negotiation of international performance standards is usually a long, if not fruitless, process requiring considerable efforts. For example, in the EU, measures to promote energy efficiency have been under serious discussion since mid-1970s, but only in the early 1990s did the EU succeed in introducing energy labelling, and the first energy efficiency standards only began to enter into force in the late 1990s (Brack *et al.*, 1999). Even if it is very difficult for the EU member countries at comparably economic and technological levels to harmonize their energy standards, the prospects for the agreements of energy efficiency or performance standards among Annex 1 countries and beyond seem remote. Indeed, developing countries led by India view strongly against sectoral performance standards. Even if common standards had eventually been established internationally, they would be expected to be driven down towards the lowest common denominator among the countries involved. Therefore, to avoid running the risk of the race to the bottom, a strong commitment by governments is required. This is even so if it is attempted to set national sectoral binding emissions targets in major economies, the most desirable form of global sectoral agreements. To that end, the significantly scaled up technology transfer and deployment, financing and capacity building by industrialized countries will be crucial to encourage and enable developing countries to make strong commitments than would otherwise have been the case.

Unlike industry-led sectoral agreements, global sectoral agreements on both sector-specific performance standards and national sectoral binding emissions targets are subject

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[5] See Bradley et al. (2007) and Meckling and Chung (2009) for further discussion on sectoral approaches to international climate agreements.

[6] See the web site of the World Business Council for Sustainable Development's Cement Sustainable Initiative at http://www.wbcsdcement.org/ (accessed on January 21, 2012).

to the UNFCCC negations. Provided that they are supported and enabled by finance and technology and are built upon a strong commitment by governments and the risk of a lowest common denominator can be avoided, these stringent forms of global sectoral agreements will be a desirable solution to address competitiveness and leakage concerns.

4.2 Grandfathering

Grandfathering gives out allowances freely to existing regulated entities in proportion to their historical emissions or output. In the US SO_2 allowance trading program (Ellerman et al., 2000) and in the first and second phases of the EU ETS, the overwhelming majority of allowances are granted for free (European Commission, 2009a).

Free allocations of allowances would be viewed as a financial contribution conferred on the regulated firms, and would thus be regarded as a subsidy under the WTO Agreement on Subsidies and Countervailing Measures (de Cendra, 2006; James, 2009; Howse, 2010). This also applies to output-based allocation or rebates to be discussed in the next subsection. This is an issue open to debate. There have been no agreements among analysts. Nor is any WTO jurisprudence on the issue (Stiglitz, 2006; Bhagwati and Mavroidis, 2007; Hufbauer and Kim, 2009). However, free allocations do not seem to raise the hackles to the same extent as border adjustments to be discussed in Section 5 for at least two reasons. The first one is that countries recognize that such allocations are considered to be necessary to gain domestic acceptance of regulated firms, in particular those carbon-intensive, often well-organized industries because they are highly mobilized politically to exert greater influence on political negotiations and policy formulation. The second reason is that although grandfathering is thought of as giving implicit subsidies to some sectors, grandfathering is less trade-distorted than the exemptions from carbon pricing (Zhang, 1998b and 1999).

This point merits some explanations. Grandfathered allowances are an unconditional lump-sum transfer from the regulating government, not tied to carbon abatement efforts or production. Because they are a fixed subsidy, they have no effect on the marginal operating costs and international competitiveness of receiving firms. However, grandfathering itself implies an opportunity cost for firms receiving permits: what matters here is not how you get your permits, but what you can sell them for - that is what determines opportunity cost. Thus, even if permits are awarded gratis, firms will value them at their market price. Accordingly, the prices of products will adjust to reflect the increased scarcity of fossil fuels. This means that regardless of whether emissions permits are given out freely or are auctioned by the government, the effects on prices are expected to be the same, although the initial ownership of emissions permits differs among different allocation methods. As a result, relative prices of products will not be distorted relative to their pre-existing levels and switching of demands towards products of those firms whose permits are awarded gratis (the so-called substitution effect) will not be induced by grandfathering. This makes grandfathering different from the exemptions from carbon taxes. In the latter case, there exist substitution effects. For example, the Commission of the European Communities (CEC) proposal for a mixed carbon and energy tax[7] provides for exemptions for the six energy-intensive industries (i.e., iron and steel, non-ferrous metals, chemicals, cement, glass, and pulp and paper) from coverage of the CEC tax on grounds of competitiveness. This not only reduces the effectiveness of the CEC tax in achieving its objective of reducing CO_2 emissions, but also makes the industries, which are exempt from paying the CEC tax, improve their competitive position in relation to those industries which are not. Therefore, there will be some switching of demand towards the products of these energy-intensive industries, which is precisely the reaction that such a tax should avoid (Zhang, 1998a and 1999). In countries such as Denmark, Norway and Sweden, where carbon/energy taxes are already implemented, energy-intensive industries are generally exempted from the taxes, either totally or partially (which leads to a large gap between effective and nominal tax rates) (Bruvoll and Larsen, 2004; Zhang and Baranzini, 2004). Since a carbon tax is intended to fall most heavily on the products of carbon-intensive industries, the exclusion of these industries from coverage of the carbon tax on the grounds of competitiveness reduces the effectiveness of the carbon tax in achieving its objective of reducing CO_2 emissions. Bruvoll and Larsen (2004) shows that although the carbon tax implemented in Norway reached as high as US$ 51 per ton of CO_2 in 1999, exempting those sectors where the carbon tax would have been otherwise effective only led to the modest reduction in emissions of 2.3% in comparison with no carbon tax case. Moreover, while such sector exemptions from carbon taxes help maintain these sector's competitiveness, they come at a substantial cost to welfare (Hoel, 1996). As empirical studies for Germany and Canada suggest, this is because the narrowing of the tax base require a higher tax rate for the non-exempt industries and thus increase the costs of achieving a given level of emissions reduction (Böhringer and Rutherford, 1997; Wigle, 2001). Böhringer and Rutherford (1997) finds that losses associated with exemptions can be substantial, even when the share of exempted sectors in overall economic activity and carbon emissions is small.

Given that firms treat free allowances in the same way as they would do purchased allowances, it is thus likely that firms pass through some, if not all, of the opportunity cost from holding allowances to consumers so that they can increase short-term profits. Pass-through rates differ significantly across sectors and among countries. Empirical studies on cost pass-through and windfall profits in the Dutch and German power sectors estimate that pass-through rates range from 60-100% for wholesale power markets (Sijm et al. 2006). Alexeeva-Talebi (2011) analyses the ability of the refining sectors to pass through carbon costs to the retailers during the first phase from 2005 to 2007 by estimating a sequence of vector error correction models covering 14 EU Member States, and concludes that the full pass-through rate (100%) for opportunity costs of carbon is very likely, while the ability of producers to pass through the CO_2 opportunity cost is estimated much lower in other sectors, such as cement and iron and steel

[7] As part of its comprehensive strategy to control CO_2 emissions and increase energy efficiency, a carbon/energy tax has been proposed by the CEC. The CEC proposal is that member states introduce a carbon/energy tax of US$3 per barrel oil equivalent in 1993, rising in real terms by US$1 a year to US$10 per barrel in 2000. After the year 2000 the tax rate will remain at US$10 per barrel at 1993 prices. The tax rates are allocated across fuels, with 50% based on carbon content and 50% on energy content (Zhang, 1998a).

(Demailly and Quirion, 2006; Smale et al., 2006). But doing so may result in a decline of market share, and thus international competitiveness concerns would not be fully alleviated (Burniaux et al., 2009). Studies by Hourcade et al. (2007) and Smith (2008) show some evidence that this has occurred, with firms receiving free allowances trading off short-term profits and longer-term market share. In the cement sector and to a less extent in the steel sector under the EU ETS, EU producers pass through the opportunity costs of the allowances to their product prices to maintain profit margins, but face market share losses (Hourcade et al., 2007). Free allocation, as practiced in the EU ETS, can reduce incentives for relocation of production capacities in the short run, i.e., investment leakage coming from a change in the location of production capacitates. However, if free allocation is not made conditional on continued operation, companies will continue to receive free allowances. Even if they continue to operate but free allocations are not made conditional on their production level (see Section 4.3 for discussion on the updating allocation, whereby current emissions (or other activity measures) determine future allocation. This has been partly the case in the EU ETS, where emissions in the first phase affected allocation in the second phase, and production in the second phase will affect allocation in the third phase.), they can still choose to reduce production in favor of imports to keep their overall profitability. Thus unconditional free allocation does not reduce operational leakage.

Thus, free allowance allocation can compensate for carbon costs, but given the limited control over the reaction of industries unconditional free allocation will undermine its ability to address competitiveness and leakage concerns. The closure rule under the EU ETS aims to correct this, specifying that installations that cease their operation are no longer given free allowances.

4.3 Output-based allocation or rebates

In order to effectively address leakage, the quantity of allowances that a company receives for free needs to be tied to its production level. As the Swedish NOx charge has specified, companies above the average standards face a net liability, while those below the average get a net payment or subsidy. Since the charge was introduced in 1992, NOx emissions per unit of useful energy produced by regulated companies have declined by 50% as a result of technology adoption and innovations in physical technology and management practices. Costs of mitigation also fall significantly (OECD, 2010). The output-based allocation operates very much like tradable emissions performance standards, and thus provides similar incentives. Because additional production receives additional allowances, such an allocation is essentially a production subsidy. This will lower the marginal costs of production, and thus improve competitiveness and reduce the incentive to relocate production away from the carbon-constrained region. The Waxman-Markey bill has taken this approach, with output-based rebates for a set of energy-intensive, trade-exposed sectors, until import allowance requirements are imposed in these sectors of those countries that have not undertaken climate efforts comparable to that of the U.S. no earlier than 2020.

Output-based updating allocation has its own controversies (Quirion, 2009). This form of allocation preserves the incentive for domestic firms to reduce emissions per unit of production, but eliminates the incentive for domestic firms to curtail production to meet emission targets. This would raise risk of non-compliance. Updating allocations involve periodically adjusting allocations over time to reflect changes in company's production. This can thus have the potential to provide perverse, undesirable incentives for not taking early actions or produce a negative dynamic incentive because companies anticipate future updates and adjust their decisions, e.g., by emitting more or keeping inefficient plants in operation (Neuhoff, 2008; Dröge et al., 2009). Such negative effects on the company's output and innovation behaviors may drive up the cost of complying with emissions limits. Moreover, practically this approach requires an update of the allocation when production is known. The EU views output-based allocation as an *ex post* adjustment, which produces a negative dynamic incentive. Therefore, the EU ETS does not allow for output-based allocation. Rather, the EU ETS is based on production capacity when deciding free allocation, which can be seen as an intermediate one between free allocation based on historical data and output-based allocation (Quirion, 2010).

Furthermore, the effectiveness of output-based allocation in addressing carbon leakage depends on the implementation stage of the production chain. If allocation is downstream, this does not necessarily address carbon leakage. As Hourcade et al. (2007) shows that the risk of carbon leakage is the highest for semi-finished products, producers might substitute carbon-intensive intermediate product, like clinker and semi-finished steel by imports that are produced in non-carbon constrained regions. This can be avoided if allocation is upstream. However, this will eliminate incentives to use carbon pricing mechanism to reduce carbon-intensive inputs in the downstream sectors. Taking these points together, output-based allocation can be used to address carbon leakage concerns, if applied to intermediate or basic inputs (Dröge et al., 2009).

4.4 Border carbon adjustments

Border carbon adjustments (BCA) aim to level the carbon playing field between domestic and foreign producers when they face different carbon constraints. BCA could come in the form of import taxes or the forced surrender of emissions allowances from domestic emissions trading schemes. This type of border adjustments focuses exclusively on imports, leveling the playing field for domestic consumption, but does nothing to address the competitiveness of exports in foreign markets. The border adjustment provision in the Lieberman-Warner bill works this way. BCA could also take the form of rebates for exports.[8] This type of BCA levels the playing field abroad, but still gives imports a comparative advantage at home. Full BCA combines these types of BCA, making adjustments for both imports and exports. This reflects the application of the destination principle to products, which suggests that products should be taxed in the country where they are consumed and not in the country where they are produced unless they are also consumed there. The border adjustment provision in the Waxman-Markey bill works this way. The bill includes both rebates for few energy-intensive, trade-sensitive sectors and free emission allowances to help not to put U.S. manufacturers at a disadvantage relative to overseas competitors. While each type of BCA has the potential to mitigate carbon

[8] See Genasci (2008) for discussion on complicating issues related to how to rebate exports under a cap-and-trade regime.

leakage, the effectiveness of BCA in avoiding carbon leakage differs depending on the coverage (sector wide or the whole economy), the source of emissions (direct emissions or both direct and indirect emissions), the scope of adjustments (imports, exports or both) and the specific emissions intensities used for adjusting emissions embodied in the products affected. If the carbon-constrained home country is less carbon-intensive than the non-carbon constrained trading partners, taxing the carbon footprint of imports using the domestic emissions intensity is more effective at reducing carbon leakage than based on the foreign emissions intensities.

A number of modeling studies has examined the effectiveness of BCA in protecting competitiveness and avoiding carbon leakage. No general agreement has been arrived yet. On the one hand, some argue that BCA would have positive effects on environment improvements as well as competitive disadvantage offset (Majocchi and Missaglia, 2002; Veenendaal and Manders, 2008). For example, using a global partial equilibrium model of the steel industry, Mathiesen and Maestad (2004) shows that border adjustments tackle leakage very effectively: a border adjustment based on average specific emissions in Non-Annex I countries can cut a carbon leakage rate to -18% from 26% without the border adjustment. Lessmann et al. (2009) finds the influences of carbon tariffs on international cooperation significantly positive. Demailly and Quirion (2008) suggests that, based on a global partial equilibrium model of the cement industry, a carbon leakage falls from 25% without BCA to − 2% or 4%, depending on the assumed level of the BCA. Ross et al. (2009) suggests BCA an effective way for U.S. climate mitigation. Dissou and Eyland (2011) finds that competitiveness would be removed by BCA in Canada. Böhringer et al. (2010) suggests that BCA is the most effective leakage avoiding complement to U.S. and EU unilateral emissions reductions. Monjon and Quirion (2011) shows that BCA is most effective to addressing carbon leakage under the EU ETS.

On the other hand, some studies have concluded that BCA would be ineffective either at increasing domestic competitiveness or improving global environment (Dong and Whalley, 2009a,b; Elliott et al., 2010). For example, Fischer and Fox (2009) suggests that BCA would not be effective at reducing global emissions. McKibbin and Wilcoxen (2009) finds modest effect of BCA to reduce leakage and to defend import-competing industries without carbon costs. Kuik and Hofkes (2010) focuses on the carbon leakage avoiding effects of the EU ETS. Their results suggest that while BCA might reduce the sectoral leakage rate of the iron and steel industry, the overall leakage reduction effect is modest. The authors find an aggregate carbon leakage rate, which is 11% without BCA, decreases to 10% if BCA is based on the direct CO_2 emissions per unit of like product in the EU and to 8% if it is based on the average direct CO_2 emissions embodied per unit of foreign production of the like product. The limited impact of BCA is partly because, as aforementioned, BCA cannot prevent leakage through the fossil fuel channel, and partly the BCA limits to imports and direct emissions, and covers neither exports nor indirect emissions. Winchester et al. (2011) suggests that BCA results in only modest reduction in global emissions and significantly reduces welfare. Therefore they conclude that BCA is a costly means of reducing carbon leakage.

In addition, there could be potential conflicts with WTO provisions and practical difficulties associated with the implementation of BCA measures.
These issues will be discussed in great detail in Section 5.

4.5 Output-based allocation or rebates versus border carbon adjustments

A number of economic modeling studies have compared which anti-leakage policy, border adjustments or output-based allocation, is more effective. The results of these studies reveal that while both policies help to protect domestic production, there is a wide disagreement on the effectiveness to limit leakage impacts (Babiker and Rutherford, 2005; Dröge et al., 2009; Fisher and Fox, 2009; Quirion, 2009; Böhringer et al., 2010 and 2011; Monjon and Quirion, 2011). In each case, the effectiveness depends on the objective, namely, limiting carbon leakages or mitigating production loss in the sectors affected, and differs among sectors and across countries. This last point emphasizes the importance of undertaking this kind of analysis using a highly disaggregated model.

Fisher and Fox (2009) simulate the effects of US$50 per ton of carbon emissions unilaterally implemented in several carbon-intensive sectors in the U.S. When the effectiveness is considered on avoided production loss, output-based allocation is most effective for most sectors. By contrast, full border adjustment, the sum of the import and export rebate, is most effective for iron and steel production and nonmetallic minerals when foreign embodied emissions are fully taxed at the foreign specific emissions rates. When the effectiveness refers to avoided carbon leakage, for most sectors full border adjustment is most effective at reducing global carbon emissions. However, the differences become rather small among the options considered.

Böhringer et al. (2010 and 2011) examine anti-leakage policies to complement the EU and U.S. unilateral policy to cut their carbon emissions by 20% relative to their baselines. In percentage changes in production and carbon leakage, their effects on the EU are bigger than on the U.S. (see Figure 3). One reason for this difference is that the EU is a more open economy than the U.S., having a larger share of foreign trade. This is true for both energy-intensive goods and fossil fuels. Another reason is that energy-intensive industries and power generation in the EU are less carbon-intensive than in the U.S., with both energy and carbon intensity of these sectors in the U.S. nearly doubling that in the EU (Mattoo et al., 2009). Differing from the aforementioned findings of Fisher and Fox (2009), Böhringer et al. (2010 and 2011) find that full border adjustment is most effective at both mitigating production loss (see Figure 4) and reducing carbon leakages (see Figure 3), in particular for the EU where such effects are much bigger for the EU as a whole and all energy-intensive sectors. Moreover, import tariffs are much more effective than export rebates in protecting competitiveness and avoiding carbon leakage (see Figure 3). Among the three anti-leakage policies, namely, import tariffs, full border adjustment and output-based allocation, output-based allocation is not only least effective at deterring carbon leakage, but also most costly, although it still provides some cost savings over unilateral climate policy when the size of the abatement coalition is confined to industrialized countries. As the coalition expands, however, output-based allocation induces excess costs as it maintains distortionary subsidies to energy-intensive, trade-exposed production, whereas the cost savings through leakage reduction declines (Böhringer et al., 2011).

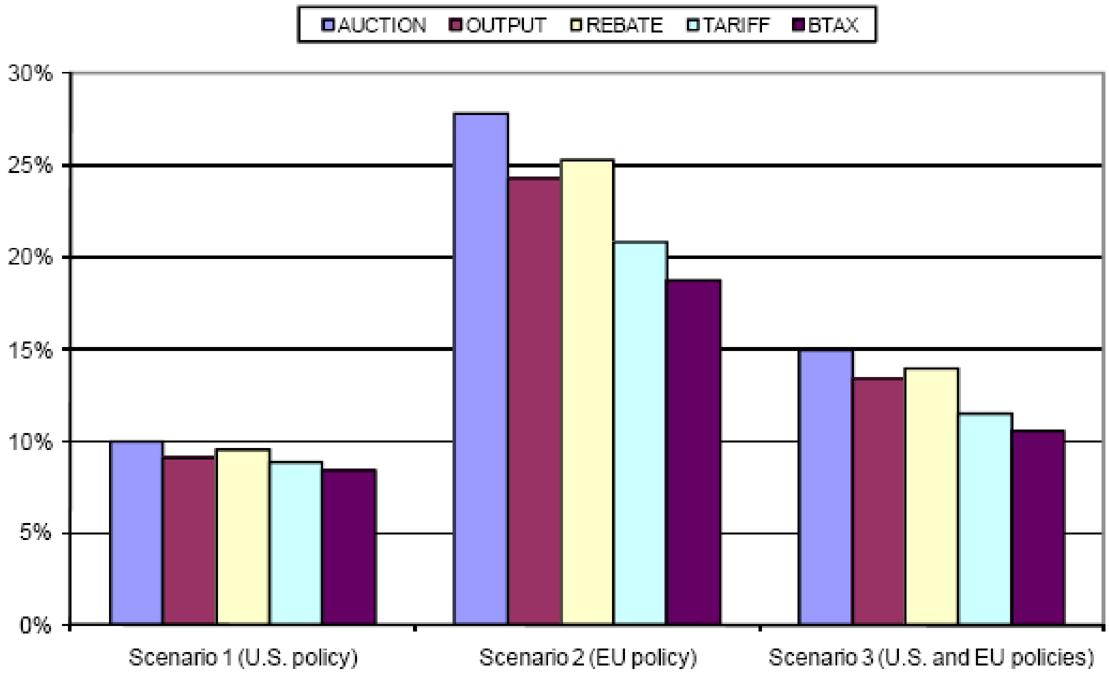

Figure 3 Global leakage effects of U.S. and/or EU CO2 emissions reductions
Source: Böhringer et al. (2010).

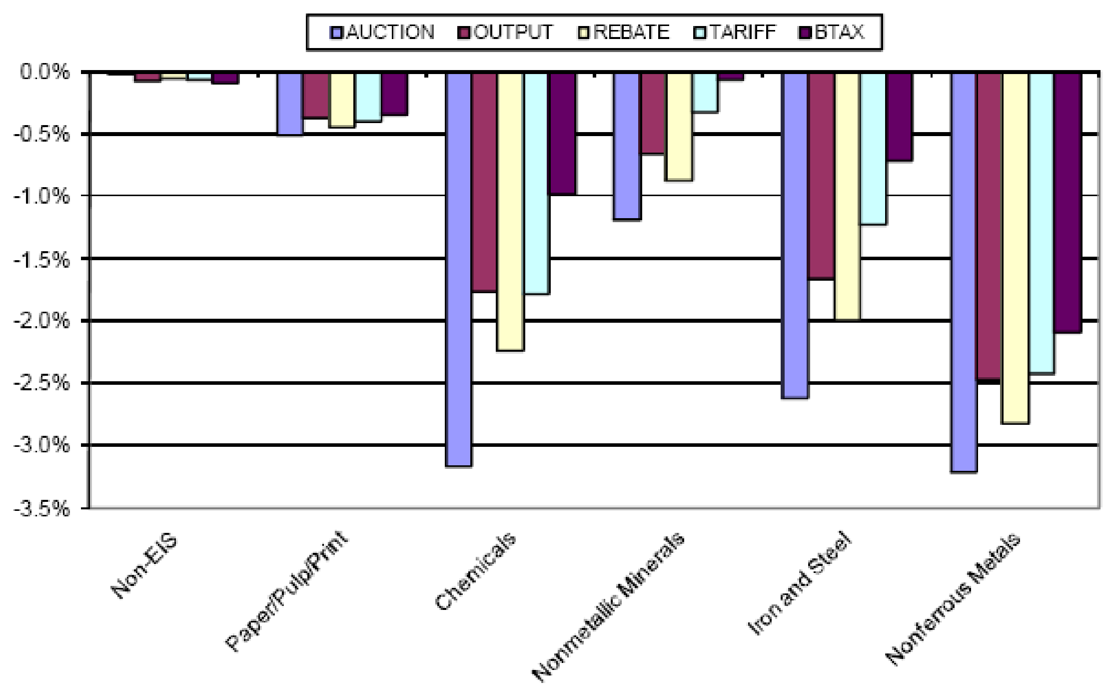

Figure 4 Effects of EU climate policies on EU production
Source: Böhringer et al. (2010).

Monjon and Quirion (2011) compares a variety of variants of border adjustments and output-based allocations to cap emissions under the EU ETS in 2016 at 85% of their 2005 levels. They find that output-based allocation is more effective than border adjustment to mitigate production losses of the sectors affected by the EU ETS. The same conclusion is reached by Rivers (2010), which examines a 20% reduction in CO_2 emissions from 2006 levels by 2020 in Canada. While this finding generally shares that from Fisher and Fox (2009), their results of the two studies differ when it comes to specific sectors. For example, in the iron and steel sector, Fisher and Fox (2009) shows that taxing foreign embodied emissions at the foreign specific emissions rates help to avoid U.S. production loss more effectively than allocation-based home rebates. This is just opposite to that of Monjon and Quirion (2011) for the EU. The specific emissions factors used are attributable to this difference. In the EU study, foreign emission intensity relative to the EU is 137%, whereas foreign emission intensity relative to the U.S. is 295%.

When it comes to tackle carbon leakage, as shown in Figure 5, Monjon and Quirion (2011) suggests that border adjustment is more effective than output-based allocation. While this is generally in line with the U.S. study, the differences in the effectiveness among the options considered are big, in comparison with the U.S. study which is impossible to rank the options. This is mainly because border carbon adjustment reduces the overall consumption of carbon-intensive steel, aluminum and cement in the EU, and therefore cuts their imports from outside the EU as well as their production and CO_2 emissions. Moreover, in most sectors, the fact that EU installations have lower specific emissions than those from outside the EU help them to win some market shares on European markets, because they face a lower increase in production cost than their foreign competitors. This will help to further reduce imports and hence emissions from outside the EU. The two variants of particularly interesting are ones that closely resemble the climate debates in the EU and the U.S.. In the third phase of the EU ETS, all allowances will be auctioned for electricity generation from 2013 onwards (with a transitional period for the ten new member states that are given the option of exempting themselves from the full auctioning rule and continuing to allocate a limited number of emission allowances to power plants for free until 2019) but industries deemed exposed to a significant risk of carbon leakage will continue to receive free allowances (European Commission, 2009a,b and 2011). The scenario labeled as *OB exposed direct*, in which auctioning of allowances is for electricity generation and output-based allocation is for director emissions in exposed sectors, simulates this case. Moreover, in the EU and the U.S., the most discussed options for a border carbon adjustment focus on imports and direct emissions. The variant labeled as *BA import direct* simulates this case. The aforementioned conclusion of the superiority of BA over output-based allocation for tackling leakage holds.

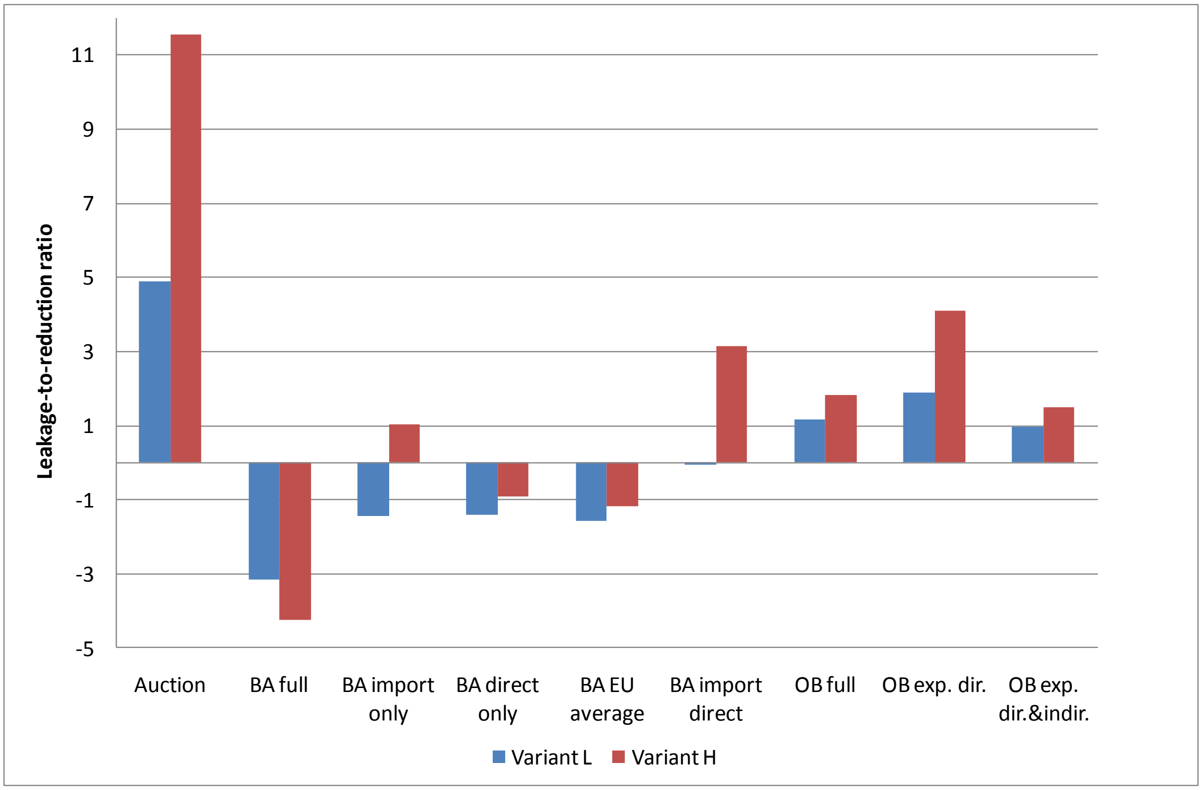

Figure 5 Aggregate carbon leakage rate
Source: Monjon and Quirion (2011).

It should be pointed out that although output-based allocation generally leads to a higher carbon leakage than border adjustment, leakage remains very limited. As shown in Figure 5, under the most efficient variant with auctioning in the power sector and output-based allocation in the cement, steel and aluminum sectors for both direct and indirect emissions, the aggregate carbon leakage rate falls to around 1–2% based on high and low values of Armington elasticities. This suggests that if leakage is considered a serious issue and that border adjustments should not be applied for some reason related to international climate change negotiations or to WTO provisions, auctioning in the power sector and output-based allocation in manufacturing industry for both direct and indirect emissions, can serve as a second-best option (Monjon and Quirion, 2011).

5. The WTO consistency, the effectiveness and methodological challenges of border carbon adjustment measures

To date, border adjustment measures in the form of emissions allowance requirements (EAR) under the U.S. proposed cap-and-trade regime are the most concrete unilateral trade measure put forward to level the carbon playing field. If improperly implemented, such measures could disturb the world trade order and trigger a trade war. Because of these potentially far-reaching impacts, this section will focus on this type of unilateral border adjustment. It requires importers to acquire and surrender emissions allowances corresponding to the embedded carbon contents in their goods from countries that have not taken climate actions comparable to that of the importing country. My discussion is mainly on the legality of unilateral EAR under the WTO rules.

5.1 Proposed border adjustment measures in the U.S. climate legislations

The notion of border carbon adjustments is not an American invention. The idea of using BCA to address the competitiveness concerns as a result of differing climate policy was first floated in the EU, in response to the U.S. withdrawal from the Kyoto Protocol. Dominique de Villepin, the then French prime minister, proposed in November 2006 for carbon tariffs on goods from countries that had not ratified the Kyoto Protocol. He clearly had the U.S. in mind when contemplating such proposals aimed to bring the U.S. back to the table for climate negotiations. However, Peter Mandelson, the then EU trade commissioner, dismissed the French proposal as not only a probable breach of trade rules but also "not good politics" (Bounds, 2006). As a balanced reflection of the divergent views on this issue, the European Commission has suggested that it could implement a "carbon equalization system … with a view to putting installations from the Community which are at a significant risk of carbon leakage and those from third countries on a comparable footing. Such a system could apply requirements to importers that would be no less favourable than those applicable to installations within the European Union, for example by requiring the surrender of allowances" (European Commission, 2008, p. 8). In light of this, various proposals about carbon equalization systems at the border have been put forward, the most recent linked to French president Nicolas Sarkozy's proposal for "a carbon tax at the borders of Europe." President Sarkozy renewed such a call for a European carbon tax on imports when unveiling the details of France's controversial national carbon tax of €17 per ton of CO_2 emissions. He defended his position by citing comments from the WTO that such a tax could be compatible with its rules and referring to a similar border carbon adjustment provision under the Waxman-Markey bill in the U.S. House to be discussed in the next two sections, arguing that "I don't see why the US can do it and Europe cannot" (Hollinger, 2009, p. 5) "not to do so would amount to "massive aid to relocations" (*The Economist*, 2009, p. 80). So far, while the EU has considered the possibility of imposing a border allowance adjustment should serious leakage issues arise in the future, it has put this option on hold at least until 2012. The European Commission has proposed using temporary free allocations to address competitiveness concerns in the interim. Its aim is to facilitate a post-2012 climate negotiation while keeping that option in the background as a last resort.

Interestingly, the U.S. legislators have not only embraced such BCA measures that they opposed in the past, but have also focused on their design issues in more details. In the U.S. Senate, the Boxer Substitute of the Lieberman-Warner Climate Security Act (S. 3036) mandates that starting from 2014 importers of products covered by the cap-and-trade scheme would have to purchase emissions allowances from an International Reserve Allowance Program if no comparable climate action were taken in the exporting country. Least developed countries and countries that emit less than 0.5% of global greenhouse gas emissions (i.e., those not considered significant emitters) would be excluded from the scheme. Given that most carbon-intensive industries in the U.S. run a substantial trade deficit (Houser et al., 2008), this proposed EAR clearly aims to level the carbon playing field for domestic producers and importers. In the U.S. House of Representatives, the American Clean Energy and Security Act of 2009 (H.R. 2998), sponsored by Reps. Henry Waxman (D-CA) and Edward Markey (D-MA), was narrowly passed on 26 June 2009, which was not passed in the US Senate and was thus not adopted. The so-called Waxman-Markey bill sets up an "International Reserve Allowance Program" whereby U.S. importers of primary emission-intensive products from countries having not taken "greenhouse gas compliance obligations commensurate with those that would apply in the United States" would be required to acquire and surrender carbon emissions allowances. The EU by any definition would pass this comparability test, because it has taken under the Kyoto Protocol and is going to take in its follow-up regime much more ambitious climate targets than U.S. Because all other remaining Annex 1 countries but the U.S. have accepted mandatory emissions targets under the Kyoto Protocol, these countries would likely pass the comparability test as well, which exempts them from EAR under the U.S. cap-and-trade regime. While France targeted the American goods, the U.S. EAR clearly targets major emerging economies, such as China and India.

5.2 WTO scrutiny of U.S. Congressional climate bills

The import emissions allowance requirement was a key part of the Lieberman-Warner Climate Security Act of 2008, and will re-appear again as the U.S. lawmakers debate and vote any climate change bill in the future. Moreover, concerns raised in the Lieberman-Warner bill seem to have provided references to writing relevant provisions in the Waxman-Markey bill to deal with the competitiveness concerns. For these reasons, I start with the Lieberman-Warner bill.

A proposal first introduced by the International Brotherhood of Electrical Workers (IBEW) and American Electric Power (AEP) in early 2007 would require importers to acquire emission allowances to cover the carbon content of certain products from countries that do not take climate actions comparable to that of the U.S. (Morris and Hill, 2007). The original version of the Lieberman-Warner bill incorporated this mechanism, threatening to punish energy-intensive imports from developing countries by requiring importers to obtain emission allowance, but only if they had not taken comparable actions by 2020, eight years after the effective start date of a U.S. cap-and-trade regime begins. It was argued that the inclusion of trade provisions would give the U.S. additional diplomatic leverage to negotiate multilaterally and bilaterally with other countries on comparable climate actions. Should such negotiations not succeed, trade provisions would provide a means of leveling the carbon playing field between American energy-intensive manufacturers and their competitors in countries not taking comparable climate actions. Not only would the bill have imposed an import allowance purchase requirement too quickly, it would have also dramatically expanded the scope of punishment: almost any manufactured product would potentially have qualified. If strictly implemented, such a provision would pose an insurmountable hurdle for developing countries (*The Economist*, 2008a).

It should be emphasized that the aim of including trade provisions is to facilitate negotiations while keeping open the possibility of invoking trade measures as a last resort. The latest version of the Lieberman-Warner bill had brought the deadline forward to 2014 to gain business and union backing.[9] The inclusion of trade provisions might be considered the "price" of passage for any U.S. legislation capping its greenhouse gas emissions. Put another way, it is likely that no climate legislation can move through U.S. Congress without including some sort of trade provisions. An important issue on the table is the length of the grace period to be granted to developing countries. While many factors need to be taken into consideration (Haverkamp, 2008), further bringing forward the imposition of allowance requirements to imports is rather unrealistic, given the already very short grace period ending 2019 in the original version of the bill. It should be noted that the Montreal Protocol on Substances that Deplete the Ozone Layer grants developing countries a grace period of 10 years (Zhang, 2000). Given that the scope of economic activities affected by a climate regime is several orders of magnitude larger than those covered by the Montreal Protocol, if legislation incorporates border adjustment measures (put the issue of their WTO consistency aside), in my view, they should not be invoked for at least 10 years after mandatory U.S. emission targets take effect.

Moreover, unrealistically shortening the grace period granted before resorting to the trade provisions would increase the uncertainty of whether the measure would withstand a challenge by U.S. trading partners before the WTO. As the ruling in the Shrimp-Turtle dispute indicates (see Box 3), for a trade measure to be considered WTO-consistent, a period of good-faith efforts to reach agreements among the countries concerned is needed before imposing such trade measures. Put another way, trade provisions should be preceded by major efforts to negotiate with partners within a reasonable timeframe. Furthermore, developing countries need a reasonable length of time to develop and operate national climate policies and measures. Take the establishment of an emissions trading scheme as a case in point. Even for the U.S. SO_2 Allowance Trading Program, the entire process from the U.S. Environmental Protection Agency beginning to compile the data for its allocation database in 1989 to publishing its final allowance allocations in March 1993 took almost four years. For the first phase of the EU Emissions Trading Scheme, the entire process took almost two years from the EU publishing the Directive establishing a scheme for greenhouse gas emission allowance trading on 23 July 2003 to it approving the last national allocation plan for Greece on 20 June 2005. For developing countries with very weak environmental institutions and that do not have dependable data on emissions, fuel uses and outputs for installations, this allocation process is expected to take much longer than what experienced in the U.S. and the EU (Zhang, 2007).

Box 2 Core General Agreement on Tariffs and Trade (GATT) principles

GATT Article 1 ('most favored nation' treatment): WTO members not allowed to discriminate against like imported products from other WTO members

[9] This is in line with the IBEW/AEP proposal, which requires U.S. importers to submit allowances to cover the emissions produced during the manufacturing of those goods two years after U.S. starts its cap-and-trade program (McBroom, 2008).

GATT Article III ('national treatment'): Domestic and like imported products treated identically, including any internal taxes and regulations

GATT Article XI ('elimination of quantitative restrictions'): Forbids any restrictions (on other WTO members) in the form of bans, quotas or licenses

GATT Article XX

"Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be constructed to prevent the adoption or enforcement by any contracting party of measures…

(b) **necessary** to protect human, animal or plant life or health; …

(g) **relating to** the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption; ..."

The **threshold for (b) is higher than for (g)**, because, in order to fall under (b), the measure must be "necessary", rather than merely "relating to" under (g).

Box 3 Implications of the findings of WTO the shrimp-turtle dispute

To address the decline of sea turtles around the world, in 1989 the U.S. Congress enacted Section 609 of Public Law 101-162 to authorize embargoes on shrimp harvested with commercial fishing technology harmful to sea turtles. The U.S. was challenged in the WTO by India, Malaysia, Pakistan and Thailand in October 1996, after embargoes were leveled against them. The four governments challenged this measure, asserting that the U.S. could not apply its laws to foreign process and production methods. A WTO Dispute Settlement Panel was established in April 1997 to hear the case. The Panel found that the U.S. failed to approach the complainant nations in serious multilateral negotiations before enforcing the U.S. law against those nations. The Panel held that the U.S. shrimp embargo was a class of measures of processes-and-production-methods type and had a serious threat to the multilateral trading system because it conditioned market access on the conservation policies of foreign countries. Thus, it cannot be justified under GATT Article XX. However, the WTO Appellate Body overruled the Panel's reasoning. The Appellate Body held that a WTO member requires from exporting countries compliance, or adoption of, certain policies prescribed by the importing country does not render the measure inconsistent with the WTO obligation. Although the Appellate Body still found that the U.S. shrimp embargo was not justified under GATT Article XX, the decision was not on the grounds that the U.S. sea turtle law itself was inconsistent with GATT. Rather, the ruling was on the grounds that the application of the law constituted "arbitrary and unjustifiable discrimination" between WTO members (WTO, 1998). The WTO Appellate Body pointed to a 1996 regional agreement reached at the U.S. initiation, namely the Inter-American Convention on Protection and Conservation of Sea Turtles, as evidence of the feasibility of such an approach (WTO, 1998; Berger, 1999). Here, the Appellate Body again advanced the standing of multilateral environmental treaties (Zhang, 2004; Zhang and Assunção, 2004). Thus, it follows that this trade dispute under the WTO may have been interpreted as a clear preference for actions taken pursuant to multilateral agreements and/or negotiated through international cooperative arrangements, such as the Kyoto Protocol and its successor. However, this interpretation should be viewed with great caution, because there is no doctrine of *stare decisis* (namely, "stand by things already established by prior decisions") in the WTO; the GATT/WTO panels are not bound by previous panel decisions (Zhang and Assunção, 2004).

Moreover, the WTO Shrimp-Turtle dispute settlement has a bearing on the ongoing discussion on the "comparability" of climate actions in a post-2012 climate change regime. The Appellate Body found that when the U.S. shifted its standard from requiring measures essentially the same as the U.S. measures to "the adoption of a program *comparable* in effectiveness", this new standard would comply with the WTO disciplines (WTO, 2001, paragraph 144). Some may view that this case opens the door for U.S. climate legislation that bases trade measures on an evaluation of the comparability of climate actions taken by other trading countries. Comparable action can be interpreted as meaning action comparable in effect as the "*comparable* in effectiveness" in the Shrimp-Turtle dispute. It can also be interpreted as meaning "the comparability of efforts". The Bali Action Plan adopts the latter interpretation, using the terms comparable as a means of ensuring that developed countries undertake commitments comparable to each other (Zhang, 2009).

In the case of a WTO dispute, the question will arise whether there are any alternatives to trade provisions that could be reasonably expected to fulfill the same function but are not inconsistent or less inconsistent with the relevant WTO provisions. Take the GATT Thai cigarette dispute as a case in point. Under Section 27 of the Tobacco Act of 1966, Thailand restricted imports of cigarettes and imposed a higher tax rate on imported cigarettes when they were allowed on the three occasions since 1966, namely in 1968-70, 1976 and 1980. After consultations with Thailand failed to lead to a solution, the U.S. requested in 1990 the Dispute Settlement Panel to rule on the Thai action on the grounds that it was inconsistent with Article XI:1 of the General Agreement; was not justified by the exception under Article XI:2(c), because cigarettes were not an agricultural or fisheries product in the meaning of Article XI:1; and was not justified under Article XX(b) because the restrictions were not necessary to protect human health, i.e. controlling the consumption of cigarettes did not require an import ban. The Dispute Settlement Panel ruled against Thailand. The Panel found that Thailand had acted inconsistently with Article XI:1 for having not granted import licenses over a long period of time. Recognizing that XI:2(c) allows exceptions for fisheries and agricultural products if the restrictions are necessary to enable governments to protect farmers and fishermen who, because of the perishability of their produce, often could not withhold excess supplies of the fresh product from the market, the Panel found that cigarettes were not "like" the fresh product as leaf tobacco and thus were not among the products eligible for import restrictions under Article XI:2(c). Moreover, the Panel acknowledged that Article XX(b) allowed contracting parties to give priority to human health over trade liberalization. The Panel held the view that the import restrictions imposed by Thailand could be considered to be "necessary" in terms of Article XX(b) only if there were no alternative measure consistent with the General Agreement, or less inconsistent with it, which Thailand could reasonably be expected to employ to achieve its health policy objectives. However, the Panel found the Thai import restriction measure was not necessary because Thailand could reasonably be expected to take strict, non-discriminatory labelling and ingredient disclosure regulations and to ban all the direct and indirect advertising, promotion and sponsorship of cigarettes to ensure the quality and reduce the quantity of cigarettes sold in Thailand. These alternative measures are considered WTO-consistent to achieve the same health policy objectives as Thailand now pursues through an import ban on all cigarettes whatever their ingredients (GATT, 1990). Simply put, in the GATT Thai cigarette dispute, the Dispute Settlement Panel concluded that Thailand had legitimate concerns with health but it had measures available to it other than a trade ban that would be consistent with the General Agreement on Tariffs and Trade (e.g. bans on advertising) (GATT, 1990).

Indeed, there are alternatives to resorting to trade provisions to protect the U.S. trade-sensitive, energy-intensive industries during a period when the U.S. is taking good-faith efforts to negotiate with trading partners on comparable actions. One way to address competitiveness concerns is to initially allocate free emission allowances to those sectors vulnerable to global competition, either totally or partially.[10] Bovenberg and Goulder (2002) found that giving out about 13% of the allowances to fossil fuel suppliers freely instead of auctioning in an emissions trading scheme in the U.S. would be sufficient to prevent their profits from falling under a carbon-constrained policy, relative to the case of no emissions constraints.

There is no disagreement that the allocation of permits to emissions sources is a politically contentious issue. Grandfathering, or at least partially grandfathering, helps these well-organized, politically highly-mobilized industries or sectors to save considerable expenditures and thus increases the political acceptability of an emissions trading scheme, although it leads to a higher economic cost than a policy where the allowances are fully auctioned.[11] This explains why the sponsors of the American Clean

[10] To be consistent with the WTO provisions, foreign producers could arguably demand the same proportion of free allowances as U.S. domestic producers in case they are subject to border carbon adjustments.

[11] In a second-best setting with pre-existing distortionary taxes, if allowances are auctioned, the revenues generated can then be used to reduce pre-existing distortionary taxes, thus generating overall efficiency gains. Parry et al. (1999), for example, show that the costs of reducing U.S. carbon emissions by 10% in a second-best setting with pre-existing labor taxes are five times more costly under a grandfathered carbon permits case than under an auctioned case. This is because the policy where the permits are auctioned raises revenues for the government that can be used to reduce pre-existing distortionary taxes. By contrast, in the former case, no revenue-recycling effect occurs, since no revenues are raised for the government. However, the policy produces the same tax-interaction effect as under the latter case, which tends to reduce employment and investment and thus exacerbates the distortionary effects of pre-existing taxes (Zhang, 1999).

Energy and Security Act of 2009 had to make a compromise amending the Act to auction only 15% of the emission permits instead of the initial proposal for auctioning all the emission permits in a proposed cap-and-trade regime. This change allowed the Act to pass the U.S. House of Representatives Energy and Commerce Committee in May 2009. Moreover, as discussed in Section 4.2, although grandfathering is thought of as giving implicit subsidies to these sectors, grandfathering is less trade-distorted than the exemptions from carbon taxes (Zhang, 1998b and 1999), which means that partially grandfathering is even less trade-distorted than the exemptions from carbon taxes.

The import allowance requirement approach would distinguish between two otherwise physically identical products on the basis of climate actions in place in the country of origin. This discrimination of like products among trading nations would constitute a prima facie violation of WTO rules. To pass WTO scrutiny of trade provisions, the U.S. is likely to make reference to the health and environmental exceptions provided under GATT Article XX (see Box 2). This Article itself is the exception that authorizes governments to employ otherwise GATT-illegal measures when such measures are necessary to deal with certain enumerated public policy problems. The GATT panel in Tuna/Dolphin II concluded that Article XX does not preclude governments from pursuing environmental concerns outside their national territory, but such extra-jurisdictional application of domestic laws would be permitted only if aimed *primarily* (emphasis added) at having a conservation or protection effect (GATT, 1994; Zhang, 1998b). The capacity of the planet's atmosphere to absorb greenhouse gas emissions without adverse impacts is an 'exhaustible natural resource.' Thus, if countries take measures on their own including extra-jurisdictional application *primarily* to prevent the depletion of this 'exhaustible natural resource,' such measures will have a good justification under GATT Article XX. Along this reasoning, if the main objective of trade provisions is to protect the environment by requiring other countries to take actions comparable to that of the U.S., then mandating importers to purchase allowances from the designated special international reserve allowance pool to cover the carbon emissions associated with the manufacture of that product is debatable. To increase the prospects for a successful WTO defence, I think that trade provisions can refer to the designated special international reserve allowance pool, but may not do so without adding "or equivalent." This will allow importers to submit equivalent emission reduction units that are not necessarily allowances but are recognized by international treaties to cover the carbon contents of imported products.

Clearly, these concerns raised in the Lieberman-Warner bill have shaped relevant provisions in the Waxman-Markey bill to deal with the competitiveness and leakage concerns. Accordingly, the Waxman-Markey bill has avoided all the aforementioned controversies raised in the Lieberman-Warner bill. Unlike the EAR in the Lieberman-Warner bill which focuses exclusively on imports into the U.S., but does nothing to address the competitiveness of U.S. exports in foreign markets, the Waxman-Markey bill included both rebates for few energy-intensive, trade-sensitive sectors[12] and free emission allowances to help not to put U.S. manufacturers at a disadvantage relative to overseas competitors. Unlike the Lieberman-Warner bill in the U.S. Senate, the Waxman-Markey

[12] See Genasci (2008) for discussion on complicating issues related to how to rebate exports under a cap-and-trade regime.

bill also gives China, India and other major developing nations time to enact their climate-friendly measures. Under the Waxman-Markey bill, the International Reserve Allowance Program may not begin before 1 January 2025. The U.S. president may only implement an International Reserve Allowance Program for sectors producing primary products. While the bill called for a "carbon tariff" on imports, it very much framed that measures as a last resort that a U.S. president could impose at his or her discretion regarding border adjustments or tariffs. However, in the middle of the night before the vote on June 26, 2009, a provision was inserted in this House bill that requires the President, starting in 2020, to impose a border adjustment - or tariffs - on certain goods from countries that do not act to limit their greenhouse gas emissions. The President can waive the tariffs only if he receives explicit permission from U.S. Congress (Broder, 2009). The last-minute changes in the bill changed a Presidential long-term back-up option to a requirement that the President put such tariffs in place under the specified conditions. Such changes significantly changed the spirit of the bill, moving it considerably closer to risky protectionism. While praising the passage of the House bill as an "extraordinary first step," president Obama opposed a trade provision in that bill.[13] The carbon tariff proposals have also drawn fierce criticism from China and India. Without specific reference to the U.S. or the Waxman-Markey bill, China's Ministry of Commerce said in a statement posted on its website that proposals to impose "carbon tariffs" on imported products will violate the rules of the World Trade Organization. That would enable developed countries to "resort to trade in the name of protecting the environment." The carbon tariff proposal runs against the principle of "common but differentiated responsibilities," the spirit of the Kyoto Protocol. This will neither help strengthen confidence that the international community can cooperate to handle the (economic) crisis, nor help any country's endeavors during the climate change negotiations. Thus, China is strongly opposed to it (MOC of China, 2009). A World Bank study by Mattoo et al. (2009) shows that such a carbon tariff would cut China's manufacturing exports by 21 percent and India's by 16 percent. No wonder that China and India warned angrily of trade wars if such border adjustment taxes were imposed (Reuters, 2009; *The Economist*, 2009).[14]

[13] President Obama was quoted as saying that "At a time when the economy worldwide is still deep in recession and we've seen a significant drop in global trade, I think we have to be very careful about sending any protectionist signals out there. I think there may be other ways of doing it than with a tariff approach." (Broder, 2009).

[14] China's stance on carbon tariffs is in conflict with its statement for importers being responsible for China's carbon emissions embodied in trade (Zhang, 2012). Being the workshop of the world and having the export-driven economy have led to a chunk of China's carbon emissions embedded in trade (e.g., Davis and Caldeira, 2010; Peters et al. 2011). China certainly wants importers to cover some, if not all, of the costs of that. However, if this consumption-based accounting of CO_2 emissions, either implicitly or explicitly, is to indicate that the responsibility for the CO_2 emissions from the production of traded goods and services lies with the consumers in importing countries, it can then be argued that the final responsibility for regulating those CO_2 emissions lies with the governments of importing countries. Given that most carbon-intensive industries in the

5.3 The effectiveness and methodological challenges of border carbon adjustments

Proponents of an EAR argue that such a threat would be effective as an inducement for major emerging economies to take on such a level of climate action at which U.S. legislation aims. However, this is questionable. The EAR under the U.S. proposed cap-and-trade regime would not apply to all imports. Rather, it would specifically target primary emission-intensive products, such as steel, aluminum, and cement. Indeed, China has become a key producer of these primary products, accounting for 36% of global steel production, 32% of global aluminum production and over 50% of global cement production in 2007. The logic for the threat of EAR is that the fear of losing market access for these products would be enough to jawbone China to take climate actions that it otherwise would not take. However, the problem with this logic is that China's burgeoning supply of these carbon-intensive products is not mainly destined for export. Rather, they are made in China for China, going primarily to meet China's own demand. As the world's largest steel export, China exported only 2% of its steel production to the European Union and less than 1% to the U.S. in 2007. As the world's largest cement producer and exporter, China consumed 97% of its cement domestically, and exported less than 1% of its production to the U.S. in 2007 (Houser 2008; Houser et al. 2008). Even if an EAR is implemented jointly with the European Union, it has little leverage effect on China because China is unlikely to raise the cost of producing 97% of its output for domestic market in order to protect a market of less than 3% of its production abroad. Moreover, this effect on the targeted country will be further alleviated by re-routing trade flows to deliver the covered products from countries that are not subject to the EAR scheme. With Japan passing the comparability test and thus being exempted from an EAR under the proposed U.S. cap-and-trade regime, imposing an EAR on Chinese steel, but not on Japanese steel, could make Japanese steel more competitive in the U.S. market than Chinese steel. That could lead Japanese steel makers to sell more steel to the United States and Japanese steel consumers to import more from China (Houser et al. 2008). In the end, this neither affects China nor protects U.S. steel producers. Böhringer et al. (2010) shows that China's and India's exports of the energy-intensive products are higher with the EU and the U.S. taking output-based allocations, exports rebates and import tariffs to complement their unilateral policy to cut their carbon emissions by 20% relative to their baselines than without any climate policies. Even if China's and India's exports of these energy-intensive products are lower when the EU and the U.S. take full border adjustment than without any climate policy, these sectors do not lose, because their aggregate production remains higher than without any climate policy.

Besides the issue of WTO consistency and the ineffectiveness of an EAR in leveraging developing countries to change behaviour, there will be methodological challenges in implementing an EAR under a cap-and-trade regime, although such practical implementation issues are secondary concerns. Identifying the appropriate carbon contents embodied in traded products will present formidable technical difficulties, given the wide range of technologies in use around the world and very different energy

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U.S. run a substantial trade deficit, this proposed EAR clearly aims to level the carbon playing field for domestic producers and importers.

resource endowments and consumption patterns among countries. In the absence of any information regarding the carbon content of the products from exporting countries, importing countries, the U.S. in this case, could adopt either of the two approaches to overcoming information challenges in practical implementation.

One is to prescribe the tax rates for the imported product based on U.S. domestically predominant method of production for a like product, which sets the average embedded carbon content of a particular product (Zhang, 1998b; Zhang and Assunção, 2004). This practice is by no means without foundation. For example, the U.S. Secretary of the Treasury has adopted the approach in the tax on imported toxic chemicals under the Superfund Tax (GATT, 1987; Zhang, 1998b). An alternative is to set the best available technology (BAT) as the reference technology level and then use the average embedded carbon content of a particular product produced with the BAT in applying border carbon adjustments (Ismer and Neuhoff, 2007). Generally speaking, developing countries will bear a lower cost based on either of the approaches than using the nation-wide average carbon content of imported products for the country of origin, given that less energy-efficient technologies in developing countries produce products of higher embedded carbon contents than those like products produced by more energy-efficient technologies in the U.S.. Mattoo et al. (2009) show that taxing the carbon footprint of imports based on U.S. domestic production would reduce China's and India's exports by around 3%, instead of 21% for China and 16% for India if a tariff is based on the amount emitted to make the imported products in China and India. However, to be more defensible, either of the approaches should allow foreign producers to challenge the carbon contents applied to their products to ensure that they will not pay for more than they have actually emitted.

6. Conclusions

In response to potentially severe climate change consequences, the OECD countries, in particular the EU, have taken the lead in cutting their greenhouse gas emissions. In the meantime, under the UNFCCC principle of "common but differentiated responsibilities," developing countries are allowed to move at different speeds relative to their developed counterparts. This difference in climate abatement commitments would persist at least until 2020, depending on when and in what format a post-2012 climate change regime emerges (UNFCCC, 2011). Thus, fragmented carbon markets and different carbon prices among trading partners will continue until then. Given the global nature of greenhouse gas emissions, the environmental effectiveness of the regulating country's efforts will be reduced if only one group of the regulating countries commit to abate their emissions while others do not. Therefore, the environmental effectiveness of such unilateral or uneven climate policies has been academic focuses and of significant policy concerns.

A large body of *ex ante* studies have quantified leakage impacts of unilateral or uneven climate policies at both the aggregated and sectoral levels. While one estimate reports an aggregated carbon leakage rate above 100% assuming the homogeneity of goods and increasing returns to scale, which differ from the usual assumptions of products differentiation and constant returns to scale under the CGE modeling, the estimated carbon leakage rates at the aggregated level tend to be much smaller than those estimates at sectoral levels. This should come as no surprise, because energy-intensive industries are major carbon emitters and are thus targeted by carbon abatement policies. Many studies have shown that these energy-intensive industries in the carbon-constrained countries would suffer substantial economic losses and shift their investment and production to non- or less carbon-constrained countries. Such a shifting will lead to high carbon leakages and thus reduce the environmental effectiveness of the carbon policy.

The fears of competitiveness losses and the environmental ineffectiveness as a result of carbon leakage are the main arguments put forward by industry lobby groups against stringent climate policies. Moreover, because potential costs are felt by these concentrated, often well-organized industries in comparison with widely-spread benefits, they are highly mobilized politically to exert greater influence on political negotiations and policy formulation. To mitigate their fears and gain their acceptance, the regulating countries often identify sectors deemed to be exposed to a risk of carbon leakage and grant these energy-intensive, trade exposed sectors some favorable treatments in the forms of exceptions from carbon pricing or free allowance allocations. This explains why *ex ante* estimates of potential carbon leakage rates are in sharp contrast with *ex post* results of environmental tax reforms and greenhouse gas emissions trading schemes that have been implemented in the EU. Indeed, the ETRs have not been significant in terms of their impact on unit production costs (below 1% in 50 cases). While there is some evidence for a decline in competitiveness in selected countries/sectors, there is no consistent pattern and it is not possible to conclude that the reform was a significant contributing factor. Analysis of cement, iron and steel, aluminum and refinery sectors does not reveal carbon leakage for these trade-exposed carbon-intensive sectors during the first phase of the EU ETS. There is also no evidence that the EU ETS in place has triggered changes in trade flows and production patterns in these sectors during this phase.

While these e*x post* analyses of the EU ETS helps us better understand competitiveness and carbon leakage impacts of the EU ETS, the insights from such analyses are of limited value for the future, because the EU ETS will become a much stricter scheme with a rising share of auctioning on the one hand and a decreasing yearly amount of the overall allowances to be handed out to industries on the other hand in the third phase 2013-2020 and beyond. Moreover, the European Commission has recognized the impact of the growing surplus of allowances, considering setting aside allowances and other options to strengthen the EU ETS. As would be expected, the costs of emitting carbon are therefore expected to rise in the carbon constrained EU or other countries that take comparable climate actions, relative to the rest of the non- or less carbon constrained world.

To level the carbon costs in order to avoid putting industries exposed to a risk of carbon leakage at a competitive disadvantage vis-à-vis their trading partners, free output-based allocations and border carbon adjustments have been put forward. The effectiveness of both policies depends on the objective, namely, limiting carbon leakages or mitigating production loss in the sectors affected, and differs across sectors and countries. Studies differ when it comes to which anti-leakage policy, border adjustments or output-based allocation, is more effective to mitigating production loss, but tend to agree that border carbon adjustments is more effective than output-based allocation to tackle carbon leakage.

However, the implementation of border carbon adjustment measures faces the effectiveness and methodological challenges. The sectors in developing countries specifically targeted by such anti-leakage measures do not necessarily lose, relative to a world without any climate polices. Moreover, the implementation of such measures would have potential conflicts with World Trade Organization provisions, depending on how they are designed and the specific conditions for implementing them (WTO and UNEP, 2009). Thus, in designing such trade measures, WTO rules need to be carefully scrutinised, and efforts need to be made early on to ensure that the proposed measures comply with them. After all, a conflict between the trade and climate regimes, if it breaks out, helps neither trade nor the global climate. Moreover, to increase the prospects for a successful WTO defence of the Waxman-Markey type of border adjustment provision, there should be: 1) a period of good faith efforts to reach agreements among the countries concerned before imposing such trade measures; 2) consideration of alternatives to trade provisions that could reasonably be expected to fulfill the same function but are not inconsistent or less inconsistent with the relevant WTO provisions; and 3) trade provisions that can refer to the designated special international reserve allowance pool, but should allow importers to submit equivalent emission reduction units that are recognized by international treaties to cover the carbon contents of imported products.

However, such anti-leakage policy, even if made WTO-consistent, is at most a short-term solution. Going forward, the global approach is the best option to level the carbon costs. The ideal solution is to have a legally binding international agreement that covers all countries, at least all major emitting economies, and sets their emissions limits. Such an agreement will enable to internalize the carbon costs and establish a global carbon price framework, thus leveling the carbon playing field. Although there is some positive sign in international climate change negotiations, such an agreement will not come any time soon. The more realistic alternative is to establish global sectoral agreements. The carbon regulating countries need to explore, with their trading partners, cooperative sectoral approaches to advancing low-carbon technologies and/or concerted mitigation efforts in a given sector at the international level. Provided that global sectoral agreements on both sector-specific performance standards and national sectoral binding emissions targets are reached, these stringent forms of global sectoral agreements will be a desirable solution to address competitiveness and leakage concerns.

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